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ORIGINAL ARTICLE

Multi-criteria decision analysis in adaptation decision-making: a flood case study in Finland

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Abstract Decision-making for the purpose of adaptation to climate change typically involves multiple stakeholders, regions and sectors as well as multiple objectives related to the use of resources and perceived benefits. Standard cost–benefit analysis can be argued to take into account easily monetised effects only. Multi-criteria decision analysis (MCDA) embedded in participatory processes can therefore play an important role in defining the decision context and exploring stakeholders' preferences. In this paper, a case study on flood protection of the Kokemäki river running through the city of Pori in West Finland was conducted. The study was realised as a MCDA workshop involving the key stakeholders of the region. The analysis produced a robust ranking of the considered flood protection alternatives. According to the stakeholders, the approach was useful as an exploratory way of gaining a deeper and shared understanding of the flood protection. It was shown that MCDA is well suited for decision-making in adaptation to climate change–enhanced extreme events.

Keywords Adaptation · Climate change · Multi-criteria decision analysis (MCDA) · Flood protection

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Introduction

Climate change alters the frequency of occurrence and severity of extreme events. The changed situation calls for adaptation, since possible natural hazards affect communities at large. This emphasises the need for participatory decision-making taking into account multiple stakeholders, regions and sectors as well as multiple objectives related to the use of resources and perceived benefits.

The assessments of the cost of climate change and adaptation were until recently predominantly carried out at high levels of aggregation (e.g. Fankhauser 1995; Tol 2002a, b; Stern 2007; EEA 2007) despite the need for analysis at lower spatial scales. Furthermore, with the exception of Stern (2007), extreme events were not included in these studies. Kuik et al. (2011) identify the lack of regionalisation of economic impact assessment as one of the weakly developed theme areas in climate change impact research. Yet, in the past few years, national study programmes in various countries as well as in the EU FP7 programme have spawned quite some regional and sectorial impact studies (e.g. Feyen and Watkiss 2011; Bubeck and Kreibich 2011; Nokkala et al. 2012; Jongman et al. 2012).

The assessment of the distribution of costs and benefits of adaptation over social groups and areas has received little attention in economic appraisal of adaptation strategies, although it would be very relevant for decision-making and acceptability of solutions. Because extreme events and adaptation to climate change affect the community as a whole, the views and objectives of different stakeholders should be taken into account in the decision-making processes. A number of studies emphasise the involvement of stakeholders and flexibility in adaptation strategies, while being less particular about precise cost estimations (Huntjens et al. 2010; Möllenkamp et al. 2010;

NONAM 2013). Indeed, it seems beneficial to combine the fields of participatory decision support processes and economic impact analysis. This was explored in the Finnish TOLERATE project (Perrels et al. 2010), where climate change–induced changes to flood risks were assessed for two river basin areas. One of them, the Kokemäki river in West Finland with the downstream city of Pori as focal point, was found to have rising flood risk. For that basin, the costs of various flood levels in current and future climate were assessed.

This paper describes a case study on the flood control in Pori. The study draws upon the hydro-meteorological and economic impact assessments reported in Perrels et al. (2010). It demonstrates the decision-making process in adaptation to climate change–enhanced extreme events. Alternative adaptation solutions were evaluated and ranked in a group decision-making process exploring the views and values of different stakeholders and aiming at reducing the climate change–enhanced flood risks to an acceptable level.

In the Nordic countries, the precipitation is expected to increase especially in winter time. A growing share of the winter precipitation will come as rain instead of snow (Ciscar 2009; Jylhä et al. 2009), having varied implications on fluvial flood risks in different parts of Finland depending on the extent of regulation and the location of the river basin (Veijalainen 2012; Perrels et al. 2010). In Finland, fluvial flood damages are often quite limited due to the low population density in the affected areas. The city of Pori is one of the few exceptions, being a larger urban settlement (~80,000 inhabitants) downstream on both sides of the Kokemäki river near its estuary. Thus, fluvial floods in Pori can get aggravated by storm surge at the Baltic Sea coast.

In future climate up to 2050, maximum discharges for Pori area floods with a 250-year return period, the expected time for a flood of a given magnitude or greater to reoccur, are expected to increase by approximately 9 %, assuming no big changes in the regulation protocol of the river–lake system. The increase implies almost a doubling of the flooding duration (Perrels et al. 2010). Even a flood with a return period of 50 years would have substantial negative impacts on city life, real estate and infrastructure in Pori given the state of the embankments in 2008. According to Perrels et al. (2010), climate change would drive up the costs of a serious flood by 15–20 %. Admittedly, in the same period economic growth might add up to 50 % to the flood cost bill.

Multi-criteria decision analysis (MCDA) (Keeney and Raiffa 1976; Keeney 1992) was used in this study to support a multi-stakeholder decision process in evaluating different flood protection alternatives in Pori. The stakeholder participation was achieved through a 1-day workshop. In a multi-criteria decision-making problem, a decision-maker uses several, usually conflicting, objectives to assess the desirability of different decision alternatives, that is, courses of action. Their benefits and costs are not transferred into monetary terms, but measured on a value scale reflecting the desirability of the options in the view of the decision-maker. Adaptation solutions for neutralising estimated increases of flood risks are typically characterised by significant uncertainty in physical and societal processes, different time profiles for the accumulation of costs and benefits and a multitude of explicit and implicit transfers of benefits and costs between stakeholder groups. MCDA helps decision-makers in structuring the problem, making the valuations and trade-offs explicit and narrowing down the number of apparently relevant alternatives. Previous applications of MCDA to participatory multi-criteria processes of environmental and infrastructure projects affecting different stakeholder groups include, for example, creating policy alternatives for a proposed coal mine (Gregory and Keeney 1994) and lake regulations (Mustajoki et al. 2004).

The remainder of the paper is structured as follows: Section "Decision structure" discusses structuring of the case study decision process. Section "Expert workshop" describes the workshop where stakeholder values were elicited. The results of the case study are analysed in section "Results and sensitivity analysis". The findings are discussed in section "Discussion", and the paper is concluded in section "Conclusions".

Decision structure

The decision-making problem in the case study was structured in four steps: (1) setting the decision context, (2) specifying the objectives to be achieved, (3) identifying alternatives to achieve these objectives and (4) determining the outcomes of the alternatives with regard to each objective. In an ideal decision-making process, identifying alternatives and objectives would be carried out in interaction with the stakeholders in order to ensure that all relevant objectives and alternatives are included. This also helps the stakeholders to commit to a common understanding and the final decisions. However, since the research group had expertise in hydro-meteorology, evaluation of socio-economic impacts of extreme events, climate change and decision analysis, the whole structuring was carried out by the research group itself without the aid of outside experts. This choice was also motivated by the fact that one of the goals of the case study was to explore the values and views of different stakeholders and that the expert workshop had for practical reasons to be limited to 1 day. The decision structure was, however, presented to the stakeholders in the expert workshop, where the opportunity to amend the definitions was given.

Decision context

The aim of the decision-making case study was to find the most suitable protection against flooding of Kokemäki river in the city of Pori in Finland, taking into account the increasing flooding risk due to climate change. The time frame to be considered was chosen to be 2005–2050, that is, 45 years. The current flood protection level was expected to fail even in case of a river flow level associated with a return period of 50 years. It was decided to collect the values of the relevant stakeholders in a 1-day expert workshop. The structuring of the decision was almost entirely done by the research group prior to the workshop.

Different sizes of potential floods were defined using their average return periods in current climate conditions. Floods with average return periods of 50 years (R50) and 250 years (R250) were chosen to illustrate the consequences of different flood sizes. Cost assessments by Perrels et al. (2010) had shown that the damages of a R250 flood are about 3–4 times more severe than those of a R50 flood. In comparison, the additional impact of climate change during the time frame is modest: from +15 % (R50) to +20 % (R250). Thus, it was decided not to unduly complicate matters in the workshop by asking the participants to imagine impacts of climate change–reinforced floods, but to limit the assessment of adaptation needs to today's R250 and R50 floods. However, climate change induces shorter return periods in 2050, and therefore, their use to denote flood sizes turned out to be somewhat confusing. Alternative concentration pathways do not show notable differences in global warming effects up to 2050, and therefore, only one climate change scenario (SRES A1B) was taken into account in the demonstration.

An appropriate set of stakeholders representing a wide range of relevant points of view was identified for the expert workshop. The participants represented concerned ministries, regional agencies and administrations, the city of Pori, insurance companies, industry, home owners and central research organisations, see Table 1. The participants were sent advance information explaining the context of the exercise, an agenda for the day and a compact collection of overhead material of state of the art knowledge on floods.

Objectives

The main sectors in Pori affected by floods are infrastructure, business and households as shown in the influence diagram in Fig. 1. Thus, the levels of protection against floods for all these sectors were included in the objectives. Although the impacts in general are multidimensional and temporally distributed, only immediate impacts for which cost assessments were feasible were considered. The implementation and maintenance costs of a flood protection alternative were taken into account in terms of life cycle cost (LCC) over the 45-year planning time frame. A second objective captures possible structural effects of protective measures on urban land use and environment, such as spoiled river view due to embankments or limitations to land use. The five objectives were grouped into two high-level objectives to denote whether they reflect the costs and structural effects or the protection level of an alternative, see Fig. 2.

Alternatives

The considered flood protection strategies were:

- Current protection level
- Stronger embankments
- Dredging
- New river arm
- Building- or building block-specific flood protection measures

Table 1 Summary of workshop participants by background and role

Type of organisation	Role in workshop/own organisation	Number
Ministries of Finance, Environment and Agriculture and the National Road administration	Expert/policy maker	4
Regional agencies engaged in flood risk planning and rescue	Expert/hazard planning	2
City of Pori	Expert/local decision-makers and prime risk carriers	1
Association of regional and local administrations	Expert/advisor	1
Insurance company	Expert/chief actuary	1
Confederation of finnish industry	Expert/advisor	1
Association of home owners	Expert/advisor	1
Research organisation (hydrology and environment)	Expert/research in decision science	2
Project researchers	Presenters and facilitators	4

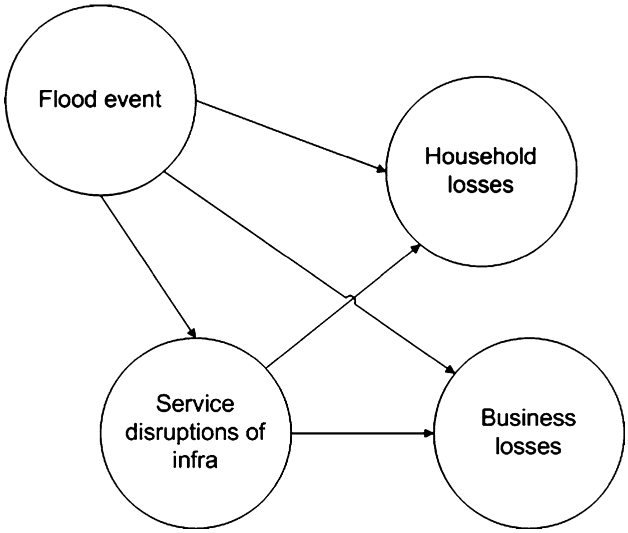

Fig. 1 An influence diagram indicating the main stakeholder groups related to the impacts of the flood case study: infrastructure sector, business sector and households

The formulation of new flood protection alternatives was based on currently implemented and readily available techniques, such as embankment and dredging. Next to these conventional options, two alternatives were added to avoid premature narrowing of the solution space. A new river arm emphasises a comprehensive urban development approach, including attempts to turn threats into opportunities. On the other hand, building-specific measures enable minimisation of risks of locking into large upfront investments and land use consequences, whereas it more easily allows inclusion of insurance products in the adaptation portfolio.

In real life, mixed strategies would certainly be considered; for example, dredging could be accompanied by some improvements in embankments. For clarity, the strategies were, however, considered in isolation from each other in the case study. The alternatives were defined in terms of protective capacity related to reference floods with return periods R50 and R250 in current climate conditions, see Table 2.

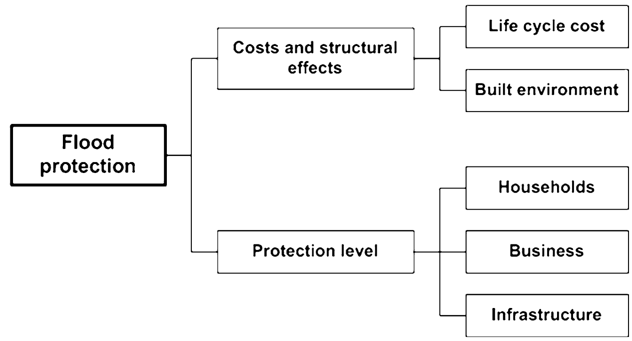

Fig. 2 Value tree denoting the hierarchy of the objectives in the decision context related to adaptation to extreme floods

Attributes

To measure how well an alternative meets the objectives, that is, the performance of an alternative, measurable attributes need to be defined (Keeney 1992). The measurement scales can be either natural or constructed. The attributes should be such that the decision-maker's preferences for different achievement levels are possible to elicit.

The net present value of the maintenance and implementation costs of an alternative during the investment period was chosen as the attribute for LCC, see Table 3. The values already estimated in (Perrels et al. 2010) can be seen in Table 4. The intervals reflect the uncertainties in the implementation costs required for each alternative to reach its goal, for example cost of the construction of a stronger embankment that would practically eliminate the adverse effects of a R50 flood.

An attribute for the built environment objective was defined to reflect the intangible aesthetics and planning of the city area as shown in Table 3. It was obvious that the performance of an alternative on this attribute can be perceived by the experts in both positive and negative ways, for example, as opportunities for innovative land use or compromises with respect to the local traditional aesthetics. Table 4 shows the outcomes of the alternatives with respect to the built environment attribute as judged by the research group and consulted experts before the expert

Table 2 Decision alternatives for protection against extreme floods

Alternative	Description
0. Zero alternative	Only some necessary maintenance of current embankments
1a. Stronger embankment R50	Stronger embankments that provide full protection against floods with return period of 50 years
1b. Stronger embankment R250	Stronger embankments that provide full protection against floods with return period of 250 years
2a. Dredging R50	More extensive dredging that provides full protection against floods with return period of 50 years
2b. Dredging R250	More extensive dredging that provides full protection against floods with return period of 250 years
3. New river arm	New river arm providing protection against floods with return period of 250 years
4. Building-specific measures	Local protection measures for critical infrastructure buildings

Table 3 The decision objectives and their associated attributes and units of measurement

High-level objective	Objective	Attribute	Unit of measurement
Costs and structural effects	Life cycle cost (LCC)	Net present value of maintenance and implementation costs during 45 years	M€
	Built environment	Effects on urban land use and environment	Qualitative
Protection level	Households	Number of houses affected and average costs per house in R50 and R250 floods	Number of houses & k€/house
	Business	Number of companies affected and average costs per company in R50 and R250 floods	Number of companies & k€/company
	Infrastructure	Water management, logistics and electricity disruption in R50 and R250 floods	Qualitative

workshop. The performance levels were discussed during the expert workshop, but any requirements to reformulate them were not raised.

The attributes for the protection-level objectives were more troublesome to define. On one hand, the benefits of flood protection will materialise only through the occurrence of a flood controlled by the selected alternative. On the other hand, knowing that a certain level of protection is installed will render value for the stakeholders by the daily sense of security and raised value of property, and therefore, the benefits are gained with certainty regardless whether floods actually happen or not.

The attributes for the households, business and infrastructure sub-objectives were defined in terms of the numbers of affected stakeholders, damage costs and duration of infrastructure disruption as shown in Table 3. The performance levels of each attribute were described using the levels of protection against the two example flood sizes R50 and R250. The estimated damages (Perrels et al. 2010) for each alternative in both cases are shown in Table 4. The uncertainties indicated by the intervals are caused by downscaling global climate models to regional climate models; the amount, usage and production of the built stock in the impacted area over the investment period; repair costs and direct monetary losses for households and business; as well as disruption of infrastructure services.

Expert workshop

The expert workshop started with an introduction of the objectives of the workshop and an overview on flooding risk in the Pori area. This was followed by an explanation of the MCDA methodology applied to the case study. The predefined flood protection alternatives were presented, and the participants had the opportunity to suggest additional ones. After agreeing on the decision structure, the preference elicitation begun.

The group collaboration software ThinkTank (GroupSystems 2013) was used by the participants to type in their inputs, and the MCDA value tree software Web-HIPRE (Helsinki University of Technology 2013) was used for calculating the aggregate results and sensitivity analyses.

Additive value function in group setting

In multi-attribute value theory (Keeney and Raiffa 1976), each decision alternative is assigned a value $v_i(x_i)$ for each attribute X_i according to the preferences of the decision-maker. The alternatives are given values from 0 for the least desirable to 1 for the most desirable alternative with regard to each attribute. The overall value V of an alternative is then calculated using an additive value function:

$$V(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} w_i v_i(x_i), \quad \begin{array}{l} w_i \in [0,1] \\ \sum_{i=1}^{n} w_i = 1 \\ v_i(x_i) \in [0,1] \end{array} \tag{1}$$

where w_i, $i \in (1, 2, \ldots, n)$ is the weight of the attribute X_i. The weights indicate a subjective trade-off between attributes, that is, how significant the decision-maker considers a change from the worst to the best level of that attribute relative to a similar change in another attribute. An additive value function exists if and only if the attributes are mutually preferentially independent, as assumed in this case study.

In the current case study, the group opinion was derived by replacing a single decision-maker's values $v_i(x_i)$ and weights w_i in Eq. (1) by their group means $\bar{v}_i(x_i)$ and $\bar{w}_i$ calculated across the experts:

$$V_G(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} \bar{w}_i \bar{v}_i(x_i), \quad \begin{array}{l} \bar{w}_i \in [0,1] \\ \sum_{i=1}^{n} \bar{w}_i = 1 \\ \bar{v}_i(x_i) \in [0,1] \end{array} \tag{2}$$

This can be seen to represent the opinions of an *average stakeholder* or the *group* as a whole, if the compromise is agreed upon. It should be noted, however, that this is not the same as taking the means of the individual overall values V of a group of stakeholders, which would in

Table 4 Performance of the alternatives with regard to the attributes

Alternatives	Costs and structural effects		Protection level		
	LCC (M€)	Built environment (effect)	Households (damage in R50 and R250 floods)	Business (damage in R50 and R250 floods)	Infrastructure (damage in R50 and R250 floods)
0. Zero alternative	2–4	Some limitations in land use (zoning)	R50: 900–2,000 houses damaged, cost average 10–60 k€/house R250: 1,500–4,000 houses damaged, cost average 20–90 k€/house	R50: 30–70 companies affected, cost average 50–150 k€/company R250: 50–200 companies affected, cost average 120–400 k€/company	R50: sewage disruption for days, local logistic disruptions for some days R250: sewage network disruption for days, logistic disruptions for weeks, electricity and telecom disruptions for days
1a. Stronger embankment R50	15–17	Landscape effects, with possible spin-off on real estate values	R50: no damage R250: same as for zero alternative	R50: no damage R250: same as for zero alternative	R50: no damage R250: same as for zero alternative
1b. Stronger embankment R250	25–28	More outspoken landscape effects, with possible spin-off on real estate values	R50: no damage R250: no damage	R50: no damage R250: no damage	R50: no damage R250: no damage
2a. Dredging R50	14–16	Environmental effects for the river ecology	R50: no damage R250: same as for zero alternative	R50: no damage R250: same as for zero alternative	R50: no damage R250: same as for zero alternative
2b. Dredging R250	19–22	Even more extensive environmental effects for the river ecology	R50: no damage R250: no damage	R50: no damage R250: no damage	R50: no damage R250: no damage
3. New river arm	35–50	Comprehensive implications for land use in Pori; landscape effects; environmental effects for the river ecology	R50: no damage R250: no damage	R50: no damage R250: no damage	R50: no damage R250: no damage
4. Building-specific measures	20–30	No large effects; possible effects on the outside looks of buildings	R50: 450–1,500 houses damaged, cost average 10–60 k€/house R250: 1,125–3,600 houses damaged, cost average 20–90 k€/house	R50: 15–53 companies affected, cost average 50–150 k€/company R250: 38–180 companies affected, cost average 120–400 k€/company	R50: critical infrastructure protected R250: some critical infrastructure protected

general be the desirable way to combine the opinions of a group. The above-described procedure was still chosen due to the technical limitations of the supportive software and because it was deemed more practical to work with one common value function instead of every expert deriving his/her own.

Preference elicitation

During the preference elicitation, each protection alternative was valued based on its performance on the attributes. For each attribute, the experts were asked to give scores from 1 to 10 to each of the alternatives, where 10 was given to the best performance and 1 to the worst. The other alternatives were given scores between 1 and 10 reflecting their performance relative to the extremes. As the alternatives 1a and 2a were assumed to perform identically on each protection-level attribute, their corresponding values were elicited only once per attribute. Alternatives 1b, 2b and 3 were grouped together for the same reason. In order to guide the process, the best and worst alternatives were pointed out in clear cases (such as new river arm performing worst and zero alternative performing best on the LCC attribute), and the experts were guided to give them scores 10 and 1, respectively. The experts were also asked to write down the rationale behind their assessments. After completing the scoring, the group means were calculated and scaled to the 0–1 value range.

Next, the attributes were weighted in a non-hierarchical manner by asking the experts to distribute 100 points among the five attributes according to their preferences. The experts were instructed to assess how significant they felt the change from worst to best level on each attribute was and to distribute the scores accordingly. The average weights across the group were calculated and scaled for the weights to sum up to 1. The group values and weights were then fed into the Web-HIPRE software to receive the aggregated group value for each alternative according to Eq. (2).

Results and sensitivity analysis

Main results

The eventual group average weights of the decision objectives are shown in Table 5. The weight of infrastructure was slightly higher than expected by the project researchers, whereas the weight of business sectors was slightly lower than expected. A fairly widely shared opinion among the experts was that companies have better possibilities to prevent flood damages than households. In addition, the weight of LCC was possibly lower than expected. One explanation for this is that a portfolio of useful public expenditures, such as schooling and medical care, with which this project has to compete over public budget money, was not considered. However, in the discussion round between the subsequent decision steps, this balancing of the overall public budget was mentioned. Preferences about cost sharing between levels of government, etc. were not covered in the case study.

Figure 3 shows the overall value per flood protection alternative calculated using Web-HIPRE. The segments of the bars indicate the value contribution of each of the objectives. A general result of the value assessment is that

Table 5 Group average weights of the decision objectives

Objective	Group average weight
Life cycle cost	0.231
Built environment	0.126
Households	0.222
Business	0.145
Infrastructure	0.277

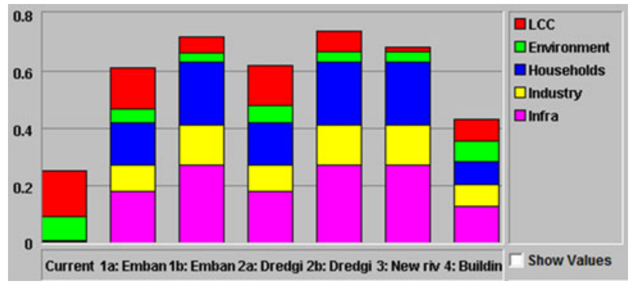

Fig. 3 Normalised total group values per flood protection alternative. The total values are distributed across the objectives according to the coloured segments whose heights indicate their relative contribution to the overall value of the alternative

the majority of the experts believe that the classical flood protection measures, such as dikes and dredging, are the best alternatives. Also, those flood protection measures that can prevent R250 flood damages are preferred over those resisting only R50 floods. This preference results despite the fact that the measures necessary to arrive at the R250 protection level are clearly more expensive. In addition to dredging and dikes, also the construction of a new river arm was considered as a good alternative, provided it also succeeds to prevent R250 flood damages.

Sensitivity analysis

Sensitivity analysis was conducted on the results to explore how changes in the weights would influence the preference order of the alternatives. The larger weight changes are needed in order to change the most preferred alternative, the more robust the results are. Figures 4 and 5 show the effects of varying the weights of the LCC and built environment objectives. Similarly, weights were varied for the households, business and infrastructure objectives.

Effect of varying the weight of the LCC objective

Figure 4 shows that the most desirable alternative varies with different weights for LCC as follows:

1. between weight 0 and 0.45: alternatives 2b and 1b are superior
2. between weight 0.45 and 0.80: alternatives 2a and 1a are superior
3. between weight 0.80 and 1: alternative 0 would be preferred, but this seems to be an irrelevant range.

Keeping in mind that the assessed weight of the LCC objective was 0.231, it can be concluded that the results are quite robust with regard to the weight of this objective. The fact that the zero alternative may become relevant only if people would attach an extremely high value to money in the nearby future fits well with the notion that willingness

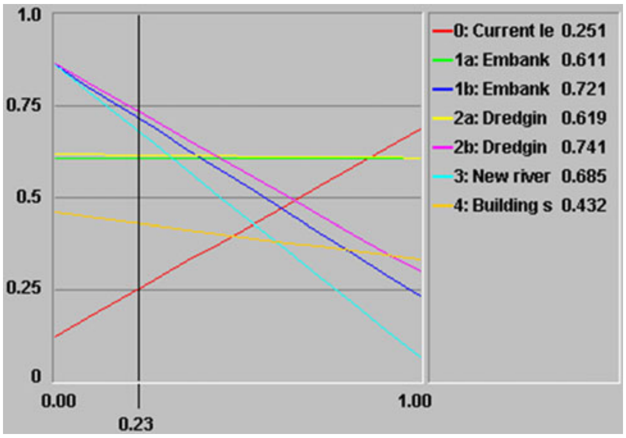

Fig. 4 Effect of varying the weight of the life cycle cost (LCC) objective on the overall values and the rankings of the flood protection alternatives

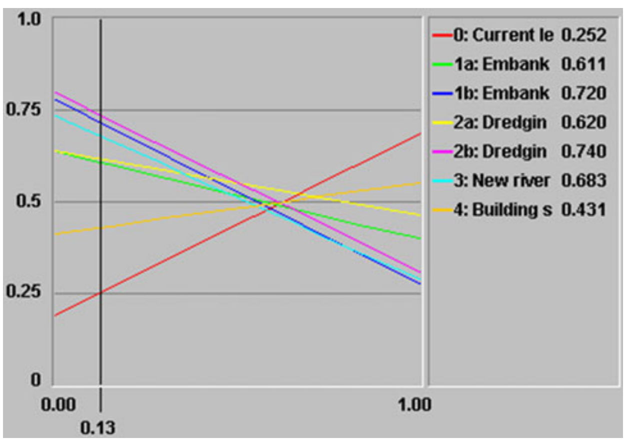

Fig. 5 Effect of varying the weight of the built environment objective on the overall values and the rankings of the flood protection alternatives

to pay for risk reduction improves when wealth levels are rising (Morone and Ozdemir 2006). Even though the representative value of the weights is uncertain, it is unlikely that LCC would get more than 80 % of the weight sum.

Effect of varying the weight of the built environment objective

It was less clear what the stakeholders exactly had in mind when assigning a certain weight to the built environment objective. A high weight could refer to the urge to maximise property value of residential areas, but it could just as well reflect the wish not to disturb the fluvial ecology.

Figure 5 shows that the most desirable alternative is less sensitive to change from the R250 protection level to the R50 level when varying the built environment weight than in the case of the LCC objective. On the other hand, the zero alternative becomes most desirable already if the built environment gets a weight of 0.66 or more. This pattern suggests that there could be possible sources of societal conflicts or risks of deadlocks on finding widely shared solutions.

Effect of varying the weights of the protection-level objectives

The pattern of the sensitivity analysis is very similar for all of the protection-level objectives. As can be seen in Fig. 6, the conclusions cannot be changed by altering the weight of the households objective. Higher level of protection is always preferred over lower ones. The same observations are true also for the business and infrastructure objectives. Yet, the alternatives 1b and 2b are so near to each other that probably other aspects than those addressed in this analysis are decisive on whether dredging or dikes are preferable.

Recommendations

It can be concluded from the main results and the sensitivity analysis that the recommendation of the MCDA workshop is that the alternatives 1b (stronger embankments that provide full protection against floods with return period of 250 years), 2b (more extensive dredging that provides full protection against floods with return period of 250 years) and 3 (new river arm providing protection against floods with return period of 250 years) are the most promising decision alternatives. Building-specific measures cannot constitute a viable flood protection measure on its own, but might complement other solutions.

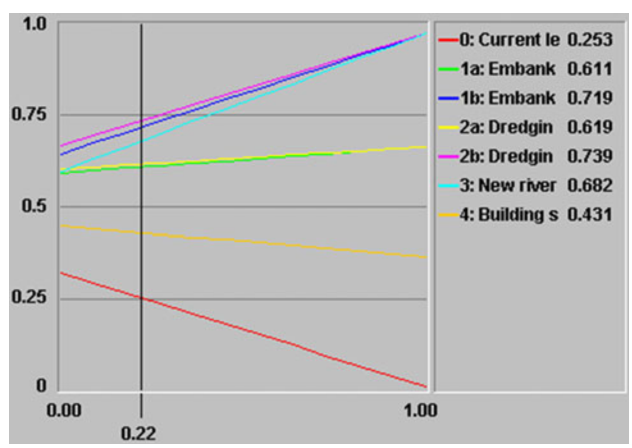

Fig. 6 Effect of varying the weight of the households objective on the overall values and the rankings of the flood protection alternatives (for the objectives business and infrastructure, the figures look very similar)

Discussion

The case study in this paper shows that MCDA is well suited for aiding the decision-making process for the purpose of adaptation to climate change. MCDA can take into account the diverse objectives and preferences of the different stakeholder groups, regions and sectors affected by adaptation decisions. By structuring the problem, the assessment can be split into smaller pieces that are easier to handle than the whole question at once. The ability to separate the objectives from values and possible prejudgements on the 'right' alternative makes it easier to focus on an objective discussion and avoid confrontations.

Performing a full MCDA process in a group setting is a challenging task that requires facilitators with expertise in the MCDA methodology and workshop experience. Careful balancing has to be made between preparatory work and topics covered in the workshop. If timetable and resource constraints permit, a multi-day workshop would be desirable, including a MCDA methodology tutorial session, because most of the stakeholders are likely to be unfamiliar with it. Another approach could be to run the MCDA valuation process with each stakeholder one-by-one, thus ensuring that he/she is able to digest each phase properly. In practice, high-level stakeholders are, however, often available only for a 1-day workshop. In such cases, the problem owner must decide in consultation with the MCDA analysts what parts of the decision-making process to focus upon in the workshop, depending on where the stakeholder inputs are most needed.

The MCDA model in the case study was quite simple due to the workshop time constraints. A more thorough evaluation could include more elaborated decision alternatives, for example in form of combinations of the basic ones or other innovative solutions. Combinations of two separate adverse events could also be included in the study; for example, heavy frost directly after a flood or pollution of the river just before the flood could easily triple the costs estimated in this study. However, the probability of occurrence of such combined events is very low.

A wide range of stakeholder groups were represented in the workshop, the only exception being the water management sector responsible for the water regulation in the Kokemäki river basin. The feedback survey conducted at the end of the expert workshop confirmed that the stakeholders thought the MCDA approach was useful as an exploratory way of gaining a deeper and shared understanding of the flood protection problem.

A robust ranking of the flood protection alternatives was achieved in the case study. According to the views expressed in the workshop, the alternatives 1b (stronger embankments that provide full protection against floods with return period of 250 years), 2b (more extensive dredging that provides full protection against floods with return period of 250 years) and 3 (new river arm providing protection against floods with return period of 250 years) are the most promising decision alternatives. However, the societal discussion would probably circle around dikes and dredging, for which also the lighter version might become relevant if the available funds are very limited. The option of a new river arm may become relevant if embedded in a wider context of city planning. Furthermore, the building-specific solutions cannot be considered as a viable principle protection solution on its own, but might be useful as a complement to less extensive dikes or dredging. The results show that the stakeholders are concerned with the risk of flooding and would rather pay for protection than be at risk. However, the ultimate decision-making in these types of questions happens at the political arena, guided also by political objectives such as allocation of the limited funds between the very disparate responsibilities of the municipality. These points of view cannot be explicitly accounted for in a MCDA workshop.

To extent the decision structure to comprise induced long-term economic effects still needs further research on their estimation techniques. However, their inclusion could alter the willingness to invest in flood protection and hence affect weights and ratings in the MCDA. In addition, real options (Trigeorgis 1996) could be included in the specification of the decision alternatives. This would add flexibility in terms of scalability of the constructions and the possibility to later modify the initial implementation according to new observations and understanding.

Conclusions

A case study on flood control of Kokemäki river running through the city of Pori in West Finland was conducted. The MCDA methodology was used to elicit the views of a representative set of stakeholders in a workshop setting. The study demonstrated the decision-making process in adaptation to climate change–enhanced extreme events. MCDA was found to be well suited for the process, because it facilitates taking into account the diverse objectives and preferences of different stakeholder groups. The analysis produced a robust ranking of the considered flood protection alternatives. The workshop participants preferred a high level of protection against floods either by embankments or dredging. The stakeholders thought the MCDA approach was useful as an exploratory way of gaining a deeper and shared understanding of the flood protection.

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