Multi-Criteria Decision Analysis (MCDA) in the evaluation of the flood risk management alternatives – the Kokemäenjoki River Basin case

Olli-Matti Verta¹ and Mika Marttunen²

¹ Centre for Economic Development, Transport and the Environment for Southwest Finland, Finland
² Finnish Environment Institute, Finland

Abstract
The Kokemäenjoki River (catchment ca 27 000 km²) flows to the Baltic Sea having average flow of 245 m³/s. The city of Pori at river delta is the most significant flood risk area in Finland. The national pilot flood risk management plan (FRMP) to the Kokemäenjoki River basin has been prepared according to the EU floods directive. The flood risk management measures in the FRMP are grouped into flood risk prevention, flood prevention, flood protection and preparedness measures. Geographically the measures can be grouped into river basin scale measures, measures in the City of Pori and measures in the City of Huiittinen.

Multi-Criteria Decision Analysis (MCDA) is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. The main objectives of MCDA in the Kokemäenjoki river basin case are: to support systematic and transparent evaluation of alternatives, to facilitate discussion in a multi-stakeholder group and to help to create a common language among participants representing different knowledge and expertise and to enhance participants’ learning and comprehensive understanding of the planning situation.

The MCDA application is divided into two analyses. The first analysis focuses on the evaluation of flood protection measures only (not described in this presentation). In the second analysis all flood risk management measures are evaluated according to their costs, technical, juridical and political feasibility as well as their impacts on floods and the status and different uses of the water course. MCDA analysis highlights the importance of subjectivity in the impacts’ significance assessment. Therefore, the opinions of the FRMP steering group about the impacts and their importance will be later included to the application in a workshop. The impact information and participants’ opinions will be used as input values in the MCDA application in which priority values for each alternative will be calculated. Finally, the results of MCDA and cost and feasibility analyses are summarized.

1 Method
Multi-Criteria Decision Analysis (MCDA), or Multi Criteria Decision Making (MCDM), is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations (Belton & Stewart 2002). MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. MCDA methods have been developed to improve the quality of decisions involving multiple criteria by making choices more explicit, rational and efficient. The goal is to create a structured process to identify objectives, create alternatives and compare them from different perspectives.

Today MCDA is an established methodology with dozens of books, thousands of applications, dedicated scientific journals software packages and university courses. MCDA applications are diverse and they cover environmental planning, fisheries management, water resources management,
MCDA has been applied in many ways and many purposes, e.g. to identify best alternative, to rank alternatives and to assess conflict potential of the alternatives. The potential benefits of the use of MCDA in environmental planning projects are summarized in Fig. 1.

**Figure 1: Benefits of MCDA in environmental planning.**

The realization of MCDA can be divided into several steps, for instance:

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<th>Step</th>
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| Analyze the decision or planning situation| a. What is the problem?  
b. Who are the key actors?  
c. What kind of constraints there are? | Framing the problem                                               |
| Identify objectives and alternatives      | a. What kind of objectives different actors have?  
b. What are the possible alternatives and what kind of impacts they have? | Objectives' hierarchy                                   |
| Define criteria and indicators            | a. What are relevant criteria and indicators in the evaluation of alternatives?  
b. Available information defines what are feasible indicators and scales? | Refined objectives' hierarchy and list of indicators and scales |
| Assess and describe alternatives' impacts | a. Analyze and summarize the results of field studies, modeling, questionnaires, interviews etc.  
b. Use expert judgments and local knowledge when needed | Impact matrix                                         |
| Find out decision makers'/stakeholders' opinions | a. What are their opinions related to alternatives' impacts and their significance  
b. Questionnaires/interviews can be applied | Respondents' preference information.               |
| Use MCDA software (not necessary step)    | a. Combine the impact data and respondents' values  
b. There are several software available e.g. Web-HIPRE (http://www.hipre.hut.fi) | Overall priority values for the alternatives for each respondent or group. |
| Analyze the results and realize the sensitivity analysis | a. What are major issues of agreement and disagreement?  
b. What are the most liked and disliked alternatives and why? | Illustrative figures and tables                     |
Implementation of the European Water Framework Directive (EU 2002) and EU Floods Directive (2007/60/EC) has raised the need of methods which can be used in the comparison of advantages and disadvantages of alternative options. MCDA provides several potential methods to support these evaluations. The cost-benefit analysis (CBA) has also been widely applied in the evaluation of alternative options in water resources management (see e.g. Brouwer & Pearce 2005). CBA has its roots in economics and is a monetarization approach. Typically, CBA provides information for decision-makers and does not require them to express value judgments (French 1986, Decision theory). CBA and MCDA are alternative ways to the problem of how to quantify or compare society’s overall benefits when one party “wins” and another “loses” (Joubert et al. 1997). Both methods have their strengths and weaknesses. Therefore, the complementary use of MCDA and CBA could be very useful.

2 The Kokemäenjoki river basin flood risk management plan (FRMP)

In the year 2007 the Southwest Finland Regional Environment Centre (Centre for Economic Development, Transport and the Environment since January 2010) began to prepare a national pilot FRMP to the Kokemäenjoki River basin. The plan has been prepared according to the EU floods directive. The FRMP has been prepared in extensive collaboration with other authorities, municipalities and actors of the river basin (Figure 2). (Verta & Triipponen 2010)

The main challenges of the FRMP are the reconciliation of flood risks and various other interests between different parts of the water body and adaptation to the climate change. The flood risk management measures are grouped in the FRMP into flood risk prevention, flood prevention, flood protection and preparedness measures. Geographically the measures can be grouped into river basin scale measures, measures in the City of Pori (area of potential significant flood risk, APSFR) and measure in the City of Huittinen (APSFR) (Figure 3). (Verta & Triipponen 2010)

Figure 2: The collaboration in the preparation of the Kokemäenjoki river basin FRMP.
3 Application to flood risk management

The main objectives of MCDA application in the Kokemäenjoki river basin case are (see fig. 1):

- Supports systematic and transparent evaluation of alternatives
- Facilitate discussion in multi-stakeholder group and helps to create a common language among participants representing different knowledge and expertise
- Supports participants’ learning and comprehensive understanding of the planning situation

The flood protection measures which are compared in the analysis are presented in Fig. 3.

The MCDA application is divided into two analyses. The first analysis focuses on the evaluation of flood protection measures only (not described in this presentation). In the second analysis all flood risk management (FRM) measures are evaluated according to their:

- costs,
- technical, juridical and political feasibility and
- impacts on floods and damages,
- impacts on economy, ecology, cultural heritage and social impacts (MCDA application).

The FRM measures’ costs are evaluated based on earlier studies, flood risk management projects and expert judgement. Both investment and operating costs are evaluated and discounted to current value using 100 year time span. The feasibility of the FRM measures is evaluated with respect to the technical, juridical and political feasibility on a rough scale of good-moderate-bad.

The FRM measures effects on floods and direct flood damages (including monetary damages as well as damages to human health, environment and to the culture) are evaluated on a scale of 0 to 100. The best measure gets 100 points and the worst 0 points, and others get points between 0 and 100. The measures are evaluated according to their effects on floods that have a yearly probability of 1 % or more. This evaluation is done according to existing flood risk management plans and expert judgement.

The FRM measures’, such as building an embankment, impacts on economy (e.g. employment and investment), ecology (e.g. ecological state of the water body) and cultural heritage (e.g. cultural landscape) as well as social effects (e.g. scenery) are evaluated on a scale of -100 to 100. FRM
measures’ impacts on flood damages are not considered in this evaluation since they are included in the evaluation described in the paragraph above. The measure that has the most positive effects is given 100 points. Measures that have no effect are given 0 points and the measure which impacts id the most negative gets -100 points.

MCDA analysis highlights the importance of subjectivity in the evaluation of the alternatives desirability and in the impacts’ significance assessment. Therefore, the opinions of the FRMP steering group about the performance values of the alternatives as well as the impacts and their importance will be later included to the application in a workshop.

In the MCDA modelling phase the information about alternatives performance values and participants’ opinions about the significance of the impacts will be used as input values. One of the major outcomes of the analysis is the calculated priority values for each alternative. Finally, the results of MCDA and cost and feasibility analyses are summarized.

4 The Kokemäenjoki River basin FRMP example

Although the Kokemäenjoki River basin FRMP has been prepared in a highly participatory process (see Fig. 2), the MCDA exercise described here has been undertaken so far only as an expert driven exercise. The evaluation of FRM measures and defining of different weight profiles is done only by one water resources management officer. Therefore, the results that presented here are only preliminary and exemplary. The results will most likely change after the application is done together with the stakeholders as described in the chapter 3.

Table 1 highlights an example about impact matrix that summarises the results of the evaluation of the FRM measures according to their costs, feasibility and impacts on floods and the status of the and different uses of the water course. Figure 4 shows how the different impacts (attributes in the MCDA) of measures are weighted in the MCDA. Different distributions of weights can be used to see how sensitive the MCDA-rankings are for the weights used (sensitivity analyse).

Table 1. An example about impact matrix that summarises the evaluation of FRM measures.
The MCDA-ranking of FRM measures according to weighting 1, conclusions about the feasibility study and measures' costs are illustrated in figure 5. There are three measures that are clearly worst in terms of feasibility: water retention and controlled flooding and new channel and individual property protections in the city of Pori. New channel and individual property protection are also the two most expensive measures. Rescue preparedness plans and run off forecast and warning systems appear to be the two most cost-efficient measures, but they are not alone adequate to meet the FRM objectives. Dredging and embankments are the only feasible extensive flood protection measures in the City of Pori. New channel is the most efficient measure in the City of Huittinen; individual property protection and embankments are not as efficient but are more cost-efficient. FRM measures cost-efficiency can also be evaluated by calculating the yearly costs per MCDA-point (see Figure 6).
Figure 6: The yearly costs of FRM measures' MCDA-points.

The MCDA-ranking's sensitivity to the given weights (1, 2 and 3) is shown in the figure 7. Although the ranking seems to be quite robust to the given weight, the weights will be later asked and discussed with stakeholders. It is also important to discuss about the impacts of FRM measures among stakeholders before giving the final priority to the measures.

Figure 7: MCDA-ranking's sensitivity to the given weights.
5 Conclusions
The preliminary MCDA exercise presented here has so far been undertaken only by the experts in the Centre for Economic Development, Transport and the Environment for Southwest Finland and Finnish Environment Institute. Therefore, we do not have any experiences how different stakeholders consider the approach presented here. The next step is to incorporate key stakeholders into the analysis and ask their opinions about the alternatives' performance values in respect to each attribute as well as the importance of attribute weights. This will be realized in a workshop in order to ensure that all participants understand the questions in a right way.

The economic assessment presented here has been done on a rough scale and not by economist. Therefore the economic assessment of FRM measures will be given more emphasis in the next steps of realization of this method.

One of the major benefits of using MCDA is that the systematic and transparent evaluation leads to better overall understanding of the decision situation and the alternatives' strengths and weaknesses. MCDA can help to understand the scale of the impacts and the uncertainty related to them. As an outcome the analysis produces the desirability of alternatives from each participant's point of view. While not giving an absolute ranking to the alternatives, since it depends on the point of view, MCDA can provide a common ground for the stakeholders for planning further recommendations.

References


