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Simulation and Analysis of Three Flood Management Strategies

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Contents

Abstract

This report describes an integrated flood catastrophe model as well as some results of a case study made in the Upper Tisza region in northeastern Hungary: the Palad-Csecsei basin (the pilot basin). The background data was provided through the Hungarian Academy of Sciences and complemented by interviews with different stakeholders in the region. Based upon these data, where a large degree of uncertainty is prevailing, we demonstrate how an implementation of a simulation and decision analytical model can provide insights into the effects of imposing different policy options for a flood risk management program in the region. We focus herein primarily on general options for designing a public-private insurance and reinsurance system for Hungary. Obviously, this is a multi-criteria and multi-stakeholder problem and cannot be solved using standard approaches. It should however be emphasized that the main purpose of this report not is to provide any definite recommendations, but rather to explore a set of policy packages that could gain a consensus among the stakeholders.

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1. INTRODUCTION

Rivers and their corridors of flood plains fulfil a variety of functions both for human use and for the natural ecosystem, i.e. they are fundamental parts of the natural, economic, and social system wherever they occur. At the same time, rivers might be the largest threats to entire areas. Besides fires, floods are the most common and widespread of all natural disasters, killing in average yearly 150 people and causing over 3 billion US $ in property damage (FEMA 00). Moreover, national average annual flood losses continue to increase. In recent years, much attention has therefore been given to the management of natural disasters and, in particular, to floods. An event that initiated the discussions was the 1992 flash flood in France, where 42 people were killed in the Vaison-la-Romaine (Samuels 98). However, despite dedicated efforts of governments and the private sector to mitigate flood hazards, problems still remain with current practices, including methods of design and construction of building utilities. Furthermore, driven by the increasing frequency of floods, the need for evaluation and strategic flood planning tools has increased (Evans 00). Consequently, in several countries it is recognized that programs for efficiently and effectively linking private and public responsibility and insurance, as well as loss mitigation, need to be created.

In the Tisza region in the northeastern part of Hungary, there are annual floods. Furthermore, extreme floods are expected every 10-12 years (Vári 99). Financial losses from floods are severe in this region, and costs for compensation to victims and mitigation strategies are increasing. In Hungary, as in other countries, the government is looking for alternative flood management strategies, where part of the economic responsibility is transferred from the public to the private sector. In the design of different flood management strategies, a key interest for the Hungarian government has been to find the balance between social solidarity and private responsibility. Today, most Hungarians perceive that the government should compensate them for the losses, but such a policy is not affordable. Moreover, there are many different interests represented by the tourist industry, other industries, farmers, environmental groups and other NGO's, (non-governmental organizations) that have to be taken into account. Consequently, there is a strong need for other loss sharing policies which different stakeholders, e.g., governments, insurers and individuals, could agree upon. Hungary is a country where as much as 20 per cent of its 93,000 square meters of territory are at risk for flooding. During the past decades, the central government has spent huge sums on building and maintaining extensive levee systems along the main rivers to protect the endangered land and communities. The government has not only taken the pre-flood responsibility, but also the post-flood responsibility. If a flood occurs in a protected area, this is considered to be the responsibility of the government, and the government has by tradition compensated the victims. For instance, after the recent devastating floods of the river Tisza, in 1999, the government paid full compensation for all damaged private properties.

During 1999, a number of interviews with stakeholders in the Upper Tisza region were performed (Vári 99), with the purpose of identifying realistic flood management strategies considered fair by the different stakeholders in the region and elsewhere. Based on the interviews, three alternative flood management policy strategies were formulated, and this report investigates the effects of imposing these strategies. The strategies are not necessarily optimal in any respect, but are constructed for the purpose of illuminating significant effects of adopting different *insurance* policies. Consequently, a main issue has been to investigate different insurance schemes in combination with level of governmental compensation. In particular, the subsidiary level has been studied, i.e., the amount of money transferred from low-risk areas to high-risk areas as well as from reasonably wealthy property owners to less wealthy ones.

This report is based on a case study of the Palad-Csecsei basin (the pilot basin), which is situated in the Szabolcs-Szatmár-Bereg County in northeastern Hungary and inhabited by 4,621 persons. This region is one of the poorest agricultural regions of Europe, and floods repeatedly strike large areas. In particular, the second largest river in Hungary, the Tisza River, flows trough the county. The pilot basin consists of eleven municipalities, of which primarily two experience flood damages.

Based upon statistical data and interviews, we demonstrate how an implementation of a simulation and decision analytical model can provide some insights on the effects of imposing different policy options for a flood risk management program in the region. We focus herein primarily on general options for designing a public-private insurance and reinsurance system for Hungary. The emphasis is on the multi-criteria and multi-stakeholder issues involved as well as the high degree of uncertainty in the background data.

Section 2 describes a tool for flood consequence simulation applied to the pilot basin with different settings for the three scenarios. Section 3 describes how the results from the simulations can be used from a decision theoretical viewpoint for investigating the relation between the different scenarios taking the different stakeholders into consideration. Section 4 summarizes a number of interviews performed with the purpose of investigating the degree of acceptance of the different scenarios. The interviewees received the simulation results beforehand and made their judgments with this background as a component. Section 5 concludes the report. Finally, there is also a set of appendices. These consists of more elaborated descriptions of the flood simulation model and the decision analytical model as well as transcripts of the interviews.

2. SIMULATING FLOOD FAILURE

Due to the inherent infrequency of natural disasters, it is impossible to predict the time, the location, or the magnitude of a flood. The shortcomings of statistical methods emphasize the role of models for evaluating new policies in presence of dependencies and lack of data, c.f. (Ekenberg 00). Needless to say, this uncertainty can be treated in a multitude of ways, but a quite common approach is to study the uncertainties explicitly by considering the flood-related variables as stochastic variables, in a probability theoretical sense.

Computer based simulations are increasingly used to understand how micro order actions affect the macro order outcome, see for instance (Axelrod 97), (Gilbert 99) and (Conte 97). Simulations are a most convenient approach in this case, since it would be very hard to determine an analytical solution to this problem. The model described below takes such an approach as well using estimated flood failures as stochastic variables in the simulations. A flood failure is something that occurs when the flood overtops a structural flood mitigation measure. The latter could, for instance, be a levee breakage. The reason for restricting the simulations to flood failures only is that insurance companies compensate damages caused by failures, but not damages caused by ground water related floods.

Nine different flood failure scenarios have been implemented in the model. This is based on the assumption that the flood can be of three different magnitudes, and that a failure can occur at three different locations. The financial damages are estimated for all flooded properties for the nine failure scenarios. Thus, in the present version of the model, we use ten different possible scenarios (nine with flood failures and one without), simulated 10 000 times over a period of ten years.

Simulation approaches seem to be the most suitable ones in these kinds of scenarios. The number of different possible outcomes of 10 possible scenarios each year over a period of 10 years is 92378 (19!/(9!·10!)) for each of the three different flood management strategies. Consequently, the number of possible scenarios makes the problem quite complex and not really suited for a more analytical treatment. This is particularly the case when having a decision analytical approach as well.

2.1 THE FLOOD MODEL

The flood model consists of different modules. A brief description of the functionality of the modules is given in the following sections. See Appendix 3 for more detailed information on the flood model and the settings. See also (Brouwers 01) and (Brouwers 02) for a more thorough discussion of the model.

Two stochastic variables are used to represent flood uncertainties. One variable *Magnitude* represents, for each simulation year, whether there is a 100-year flood, a 150-year flood, a 1000-year flood, or no flood. The probabilities for these events are 1/100, 1/150, 1/1000 and 1-(1/100+1/150+1/1000), respectively. The other variable *Failure* represents whether the flood causes a levee failure at one or none of the three locations. The following probability distributions for these 10 possibilities are used.

Magnitude	Failure	Probability
100-year flood	Location 1	0,12
100-year flood	Location 2	0,20
100-year flood	Location 3	0,28
150-year flood	Location 1	0,18
150-year flood	Location 2	0,22
150-year flood	Location 3	0,40
1000-year flood	Location 1	0,19
1000-year flood	Location 2	0,33
1000-year flood	Location 3	0,45
No flood	Location 1-3	0,00

Table 1 Probabilities for failures at different locations (From (VIT 99))

Based on this, the stochastic variables are assigned random values through a Monte-Carlo simulation. These outcomes are passed to the *Catastrophe module*, where the value of the stochastic variable *Failure* is checked. For each of the nine failure scenarios, the Catastrophe module calculates the inundated land area as well as the water level.

The *Spatial module* calculates the vulnerability of inundated land. The module uses a grid representation of the pilot basin with 1551·1551 cells, where each cell represents an area of 10 square meters. For each cell there are several relevant parameters, e.g., soil type, land-use pattern, digital elevation, and property value. In the simulations, only structural flood losses are considered, why agricultural data is omitted.

For each simulated year, when a flood failure has occurred, the financial consequences for the different stakeholders are collected and saved in the Consequence Module. The module calculates, for each inundated cell, the financial consequences, based on property values and vulnerability for all inundated cells. The latter values are received from the Spatial Module. The structural losses are estimated by a loss-function, which considers initial property value and vulnerability as well as level and duration of inundating water.

The stakeholders represented in the flood model are the municipalities, the insurance companies, the individual property owners, and the central government. In the end of each simulated year, the financial situations for all agents are updated (Hansson 01). If there was a failure, the property values are reduced for the affected cells. Premiums are paid annually, but individual property owners can normally choose whether to buy insurance or not. This choice affects the outcome both for the individuals and for the insurance company. The financial consequences also depend on the current flood management strategy, i.e. the compensation level from the government and the insurance companies.

2.2 SIMULATIONS

This section describes the settings for the simulations, and a description of the financial indicators that are being examined. The indicators from the simulations are:

- **Governmental load**: Compensation from government (in addition to subsidies and contribution to re-insurance fund in Scenario 3).
- **Balance for the insurance companies**: Income in the form of premiums for flood insurance, subtracted by the compensation paid to property owners.
- **Balance for entire pilot basin**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums. The individual balances are aggregated for the entire pilot basin (all municipalities).
- **Balance for individual property owners**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums.
- **Balance per municipality**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums. The individual balances are aggregated per municipality.

In this part, only the results concerning the entire basin, the insurance companies and the central government are presented. Full simulation results are provided in Appendix 4.

The results of the simulations of the different flood management strategies are described in terms of financial consequences. For readability, the results are aggregated according to the following distribution of outcomes.

Number of outcomes
8818
431
266
345
140
Total 10000

Table 2

This means that the outcomes are collected in groups in descending order by the magnitude of losses. Thereafter, a weighted mean of the losses is calculated. This will be further explained in section 2.2.2.1 below. The total non-aggregated material is provided in Appendix 4.

2.2.1 Policy Scenario 1: Modified Current Scenario

This scenario is a continuation of the current policy strategy in Hungary, where the government has the main economical responsibility. The assumptions for this scenario are the following:

- The government compensates 60 per cent of property damages.
- 30 per cent of the households have private (bundled) property insurances (in which 2 per cent of the total premium accounts for flood insurance).
- Holders of private (bundled) insurance are compensated by 80 per cent by the insurance companies.
- The insurance premium is not risk-based. It is based on the property value (2 per cent of the property value per year).

2.2.1.1 Governmental Load

The costs for the government equal zero in most 10-year periods (in over 88% of the periods). No flood failures occurred during these decades.

Probability	Weighted loss
0,8818	0
0,0431	-9 372 425
0,0266	-122 222 481
0,0345	-227 255 130
0,0140	-794 509 286

Table 3

However, out of 10 000 simulations, 431 times the costs were greater than zero, but less than 30 million HUF. In 266 cases the costs were between 100 and 150 million HUF. In 345 cases the costs were between 200 and 450 million HUF, were the absolute majority of the outcomes approximated 210-230 million HUF. In 140 cases, the costs were between 800 and 1000 million HUF. See Appendix 4. The right column in Table 3 denotes the weighted costs divided by the number of occurrences within each interval, i.e.,

$$\sum_{i\in I_j} p_i c_i \Big/ \sum_{i\in I_j} p_i \ ,$$

where p_i is the number of occurrences of the cost c_i, and I_j, j=1,…,5, are the respective index sets with 8818, 431, 266, 345 and 140 elements.

2.2.1.2 Balance for Insurance Companies

In the balance for the insurance companies, only premium incomes from the pilot basin are considered. Note that only 30 per cent of the property owners in this region have property insurances as compared to 60 per cent in Hungary in total.

Probability	Weighted loss
0,8818	2 276 800
0,0431	-3 936 425
0,0266	-54 470 117
0,0345	-96 047 548
0,0140	-313 335 200

Table 4

The simulations show that the insurance companies make a small profit in about 88% of the decades. This is because they receive flood premiums (2 per cent of the bundled property insurance premium). In decades with minor flood failures the balance is slightly negative; premiums are not sufficient to cover for compensations. In extreme decades the shortage is even larger, in 231 time-periods the deficit is greater than 100 million HUF. In the 140 decades with most failures, the deficit amounts to over 300 million HUF.

2.2.1.3 Balance for Entire Pilot Basin

The results for the individuals vary considerably; mostly depending on the location of the property. Below the balance for the property owners aggregated over the entire pilot basin is shown.

Probability	Weighted loss
0,8818	-2 276 800
0,0431	-17 932 566
0,0266	-230 715 672
0,0345	-434 214 423
0,0140	-1 540 519 800

Table 5

In most decades the property owner pays premiums without retrieving any compensation, since no flood failure occurs. When a failure occurs, the property owner is compensated by the government by 60 per cent of damages, and is also compensated by the insurance company by 80 per cent of the damages. Because of this double compensation, some property owners gain economically if there is a flood failure. Since the premiums are based on the property value only, the risk of the location is not considered. This means that property owners with insurance in low-risk locations subsidise the premiums for those living in high-risk locations.

2.2.1.4 Summary Scenario 1

1. The governmental load is extensive in this scenario, compensations to individual property owners are high, in extreme occasions up to 1000 millions HUF.
2. Insurance companies in the pilot basin become insolvent when there is a flood failure. As only 30 per cent of the property owners are insured, the risk reserve is insufficient.
3. Property owners with insurance perform very well. They are double compensated; i.e. they are (highly) compensated by the government as well as by the insurance companies. The premiums are not risk based, why a person in a high-risk area pays a subsidised premium. Some individuals in high-risk areas can gain economically from floods.
4. The pilot basin balance is negative in all decades, since costs for premiums are paid. The costs in 140 cases were more than 1 500 million HUF.

2.2.2 Policy Scenario 2: Private Based Insurances

In this scenario, the responsibility is partly shifted from the government to the individual property owner. This is done by lowering the compensation from the government as well as the level of compensation from the subsidised property insurance (called *insurance 1*). Furthermore, an additional risk-based premium insurance (*insurance 2*) is introduced. The assumptions are the following:

- The government compensates 30 per cent of property damages.
- 30 per cent of the households have a bundled insurance, in which 2 per cent of the total premium accounts for flood insurance. This is referred to as insurance 1.
- Holders of insurance 1 are compensated by 40 per cent by the insurance companies.
- The premium of insurance 1 is based on the property value (1 per cent of the property value per year).
- Holders of risk-based insurance 2 are compensated by 100 per cent.
- The premium of insurance 2 is risk-based. It is calculated from the expected damage per municipality, divided by the number of properties in the municipality.

2.2.2.1 Governmental Load

As in the previous scenario, no compensation is paid to the property owners 88% of the decades. In 431 decades the losses were around 4 million HUF. In 266 decades there compensations were about 61 million HUF, etc. The largest load for a decade was 514 millions HUF, which, needless to say, is a considerably smaller load than in Scenario 1.

Probability	Weighted loss
0,8818	0
0,0431	-4 686 212
0,0266	-61 111 241
0,0345	-113 627 565
0,0140	-397 254 643

Table 6

2.2.2.2 Balance for Insurance Companies

The insurance companies receive premiums from two different types of insurances; with subsidised premiums (30 per cent uptake rate in the pilot basin) and with risk-based premiums (5 per cent uptake rate), respectively.

Probability	Weighted loss
0,8818	2 469 598
0,0431	-4 074 660
0,0266	-31 356 868
0,0345	-57 104 532
0,0140	-212 081 938

Table 7

The balance for the insurance companies is calculated from the income in form of premiums, both subsidised and risk-based, subtracted by expenditures in form of compensation. The resulting balance is positive in most decades. In the majority of simulations the balance is about 2.5 millions HUF. The insurance companies manage to stay solvent even for minor flood failures; this can be contributed to the risk-based insurance. When flood failures occur, the insurance companies pay less compensation than in Scenario 1. The reason for this is the low compensation level for the subsidised insurance 1, in combination with the low uptake rate for the risk-based insurance 2. The 140 most severe losses exceeded 200 millions HUF.

2.2.2.3 Balance for Entire Pilot Basin

A property owner, who has both subsidised insurance 1 and risk-based insurance 2, pays large premiums if the property is located in a high-risk area. Premiums for the region amount to almost 2.5 million HUF per decade. When floods occur there is compensation from insurance companies as well as from the government. However, the worst-case losses for the basin are severe.

Probability	Weighted loss
0,8818	-2 469 598
0,0431	-22 480 543
0,0266	-314 940 162
0,0345	-586 785 004
0,0140	-2 039 027 705

Table 8

2.2.2.4 Summary Scenario 2

1. The governmental load is substantially smaller than in Scenario 1. The largest loss is 514 million HUF. The reason for this is that the compensation level is considerably lower.
2. The pilot basin balance shows a more negative result, since risk-based premiums are expensive for the property owner.
3. Insurance companies are showing a more balanced result than in Scenario 1. The incomes are a bit lower and the expenditures are smaller. The major shortage is 272 million HUF.
4. Since only 5% of the property owners are assumed to have risk based insurance, most of them are worse off than in Scenario 1,. Risk-based premiums are very expensive in two of the municipalities. However, when floods strike highly insured households, they receive high compensation. This is because risk-based insurance compensates to 100 per cent in addition to compensation from government and insurance 1. On the other hand, over the entire basin, the effects can be severe with a reasonably large probability of losses over 2 billions HUF.

2.2.3 Policy Scenario 3: Mandatory Fee to Catastrophe Fund

In this scenario, the government compensates flood failure victims from a catastrophe fund. However, it is mandatory for the property owners to pay a fee to that fund. The compensation for losses is 60 per cent. The fee is not risk-based and cross-subsidised in two ways: (i) property owners in high-risk locations are subsidised by property owners in low-risk locations (MUN 01), and (ii) low-income households are subsidised by the government who pays the fees (IIASA 99). The relatively low compensation is intended to stimulate property owners to take own mitigation precautions. If the catastrophe fund runs out of money, the government reimburses the fund. The assumptions are the following:

- The insurance companies are substituted by a governmentally controlled catastrophe fund.
- A mandatory subsidised fee is introduced.
- The yearly premium for the mandatory insurance is 1.5 per cent of property value.
- The property owners receive 60% compensation.
- The government subsidises insurance premiums (fees) for low-income households. 60 per cent of the property owners in the pilot basin are considered to be low-income households.
- No description of the balance for the insurance companies is included, since insurers are re-insured by the fund.

2.2.3.1 Governmental Load

The governmental load in Scenario 3 consists of the money that is transferred from the government to the fund when the balance of the fund is negative in addition to the premium subsidies for the low-income households. For low-income households, the government subsidises the premiums.

The load of the government is in most cases 2.2 million HUF. This is the mandatory fee from the non-subsidised households (40% of the property owners) in the pilot basin. When the re-insurance fund is unable to cover the claims, the government reimburses these deficits. It occurs in 1182 of 10 000 simulations. However, when this occurs, the magnitude of the loss is at 751 occasions more than 100 millions HUF. In the 140 most extreme decades, the load ranged from -790 million HUF to over -1 billion HUF.

Probability	**Weighted loss**
0,8818	2 214 540
0,0431	-7 157 885
0,0266	-120 007 941
0,0345	-225 040 590
0,0140	-792 294 746

Table 9

2.2.3.2 Balance for Entire Pilot Basin

In most years, the loss for the basin is just over 2 million HUF. However, the balance for the basin can be severe, with a maximal loss of 2.4 billion HUF.

Probability	Weighted loss
0,8818	-2 214 540
0,0431	-24 083 531
0,0266	-287 400 329
0,0345	-532 476 511
0,0140	-1 856 069 540

Table 10

Note that the balance never becomes positive. This is due to the low compensation level (60 per cent).

2.2.3.3 Summary Scenario 3

1. The balance for the catastrophe fund is rather positive during most decades.
2. The costs for the government are higher than in the other scenarios, due to the cost for contribution to the fund, and aid to the low-income households.
3. The insurance companies suffer no losses whatsoever. Neither, they gain anything in this scenario.
4. The municipalities show a negative balance. The flood compensation is low. Furthermore, in the scenario there is no possibility for the individuals to buy extra insurance.

3. DECISION ANALYSIS OF THE SCENARIOS

Above, we have focused primarily on some quite general options for designing a public-private insurance and re-insurance system for Hungary. As has been noted, this is a multi-criteria and multi-stakeholder problem. This section demonstrates a methodology for further investigating the scenarios from a decision analytical viewpoint.

3.1 The EDM Method

This section is a summary of the description of EDM in Appendix 5. The method used for evaluating the flood risk management policy decision problem in the Upper Tisza Basin (UTB) is based on the Delta method (Danielson 98). It has been further developed and extended to handle a model in which several stakeholders' outcomes can be handled on a per consequence basis. Thus, it is a multi-criteria extension to the basic probabilistic method. Further, the use of multi-level trees in this context, previously only a theoretical possibility, has now been field-tested.

In general, the EDM process is carried out in a number of steps. The first step is a bit special, since there is much information to collect. The initial information is gathered from different sources. Then it is formulated in statements and entered into the computer tool. Following that, an iterative process commences, where step by step the decision-makers gain further insights. During this process, the decision-makers receive help in realizing which information is missing, is too vague, or is too precise. They might also change the problem structure by adding or removing consequences or even entire alternatives, as more information becomes available.

In some cases, the first information collection phase can be a very long and tedious step. Sometimes, it might take man-months. In other cases, it might only require a few half-day discussions with experts. It is impossible to describe any typical case because the situations are too diverse. In the Upper Tisza Basin case, much work, ranging from interviews to simulation, was required.

After the data collection phase, a modeling task commences where the decision-maker structures and orders the information. Given the set of stakeholders, a smaller number of reasonable courses of action and identification of relevant consequences are compiled. In the UTB case, simulation results were clustered into meaningful sets. There is no requirement for the alternatives to have the same number of consequences. However, within any given alternative, it is required that the consequences are exclusive and exhaustive, i.e. whatever the result, it should be covered by the description of exactly one consequence. This is unproblematic, since a residual consequence can be added to take care of unspecified events.

The probability and value statements plus the weights are represented by interval constraints and core intervals described later. Intervals are a natural form in which to express such imprecise statements. It is not required that the consequence sets are determined from the outset. A new consequence may be added at a later stage, thus facilitating an incremental style of working.

3.1.1 Decision Frames

In EDM, a decision problem is represented by a *decision frame*. The idea with such a frame is to collect all information necessary for the model in one structure. This structure is then filled in with user statements. All the probability statements in a decision problem share a common structure because they are all made relative to the same decision frame. They are translated and collected together in a *probability base*. For value statements, the same is done in a *value base*. Finally, stakeholder weights are also supplied.

In practice, a model of the situation is created with stakeholders, relevant courses of action, and their consequences when specific events occur. A decision frame represents the model. The courses of action are called alternatives in the user model, and they are represented by consequence sets in the decision frame. Following the establishment of a decision frame in the tool, the probabilities of the events and the values of the consequences are subsequently filled in. A part of the user multi-level tree for UTB is shown in figure 3.1. For the first scenario, the three most likely outcomes are shown with their probability and value ranges. The last level contains the local weights of the stakeholders, as described below.

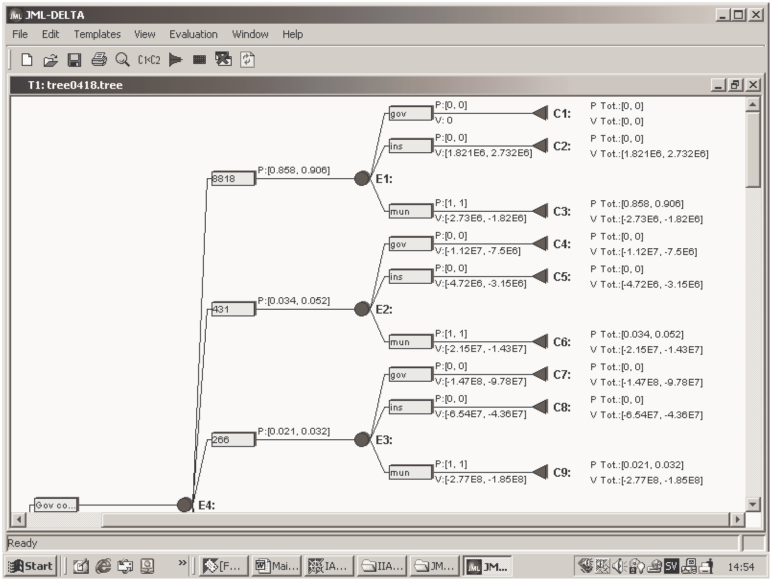

Figure 3.1: A multi-level tree for UTB

A decision frame must capture the structure of the tree internally in the tool once transformed into one-level form. A one-level tree consists primarily of sets of consequences. Then, there are statements of probability and value collected in structures called constraint sets and cores.

A collection of interval constraints concerning the same set of variables is called a *constraint set*. For such a system to be meaningful, there must exist some vector of variable assignments that simultaneously satisfies each inequality in the system. In other words, a consistent constraint set is a set where the constraints are at least not contradictory.

The *orthogonal hull* is a concept that in each dimension signals which parts are definitely incompatible with the constraint set. The orthogonal hull can be pictured as the result of wrapping the smallest orthogonal hyper-cube around the constraint set.

Constraints and core intervals have different roles in specifying a decision situation. The constraints represent "negative" information, which vectors are not part of the solution sets. The contents of constraints specify which ranges are infeasible by excluding them from the solutions. This is in contrast to core intervals, which represent "positive" information in the sense that the decision maker enters information about sub-intervals that are felt to be the most central ones and that no further discrimination is possible within those ranges.

As for constraint sets, the core might not be meaningful in the sense that it may contain no possible variable assignments able to satisfy all the inequalities. This is quite similar to the concept of consistency for constraint sets, but for core intervals, the requirement is slightly different. It is required that the focal point is contained within the core.

Together, constraint sets and cores delimit the shape of the belief in the numerical values for the variables, see figure 3.2.

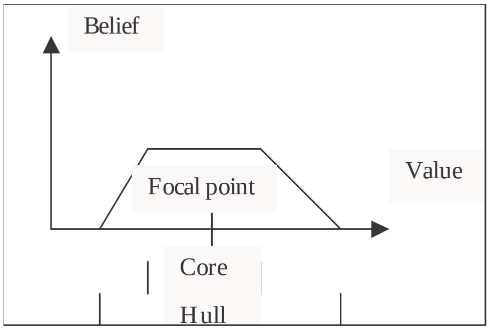

Figure 3.2: The hull, core and focal point for a variable

3.1.2 Evaluations

Which value does a particular decision have? The ultimate comparing rule of an evaluation in EDM as well as in many other methods is the expected value (EV), sometimes instantiated as the expected utility or the expected monetary value. For *s* stakeholders, this leads to the expression

$$EV(A_i) = w_1 (p_{1i_1}v_{1i_1} + \ldots + p_{1i_n}v_{1i_n}) + \ldots + w_s (p_{si_1}v_{si_1} + \ldots + p_{si_n}v_{si_n}),$$

where w_i, i=1,...,s, is the importance weight of stakeholder i.

Fortunately, in the UTB case, the decision trees are symmetrical with respect to the stakeholders, i.e. the trees, the alternatives, the consequences, and thus the probabilities coincide. This leaves us with differing values and weights.

When a rule for calculating the EV for decision frames containing interval statements is established, the next question is how to compare the courses of action using this rule. It is not a trivial task, since usually the possible EVs of several alternatives overlap. The most favorable assignments of numbers to variables for each alternative usually render that alternative the preferred one. The existence of more than one reasonable alternative means that for different consistent assignments of numbers to the probability and value variables, different courses of action are preferable. When this occurs, how is it possible to find out which alternative is to prefer?

Let $\delta_{12} = EV(A_1) - EV(A_2)$ be the differences in expected value between the alternatives. If there are more than two alternatives, pairwise comparisons are carried out between all of them. It makes sense to evaluate the *relative strength* of A_1 compared to A_2 in addition to the strengths themselves, since such strength values would be compared to some other strengths anyway in order to rank the alternatives. The relative strength between the two alternatives A_1 and A_2 are calculated using the formula

$$mid(\delta_{12}) = [max(\delta_{12})+min(\delta_{12})]/2 = [max(\delta_{12}) - max(\delta_{21})]/2$$

3.1.3 Cutting the Hull

The *hull cut* is a generalized sensitivity analysis to be carried out in a large number of dimensions. In non-trivial decision situations, when a decision frame contains numerically imprecise information, the different principles suggested above are often too weak to yield a conclusive result by themselves. Only studying the differences in the expected value for the complete bases often gives too little information about the mutual strengths of the alternatives.

A natural way to continue is to consider values near the boundaries of the constraint intervals as being less reliable than the core due to the former being deliberately imprecise. If dominance is evaluated on a sequence of ever-smaller sub-bases, a good appreciation of the strength's dependency on boundary values can be obtained. This is taken into account by cutting off the dominated regions indirectly using the hull cut operation. This is denoted *cutting* the bases, and the amount of cutting is indicated as a percentage β, which can range from 0% to 100%. For a 100% cut, if no core is specified, the bases are transformed into single points, and the evaluation becomes the calculation of the ordinary expected value. It is possible to regard the hull cut as an automated kind of sensitivity analysis. Since the belief in peripheral values is somewhat less, the interpretation of the cut is to zoom in on more believable values that are more centrally located.

In Figure 3.3, the evaluation of the three UTB scenarios is shown as three pair wise comparisons between the alternatives respectively. The x-axis shows the cut in percent ranging from 0 to 100. The y-axis is the expected value difference δ_{ij} for the pairs. The cone (which need not be linear if comparative statements are involved) consists of three lines. For comparing alternatives A_1 and A_2, the upper line is max(δ_{12}), the middle is mid(δ_{12}), and the lower is min(δ_{12}). Thus, one can see from which cut level an alternative dominates weakly, markedly, and strongly. As the cut progresses, one of the alternatives eventually dominates strongly. The cut level necessary for that to occur shows the separability between the expected values.

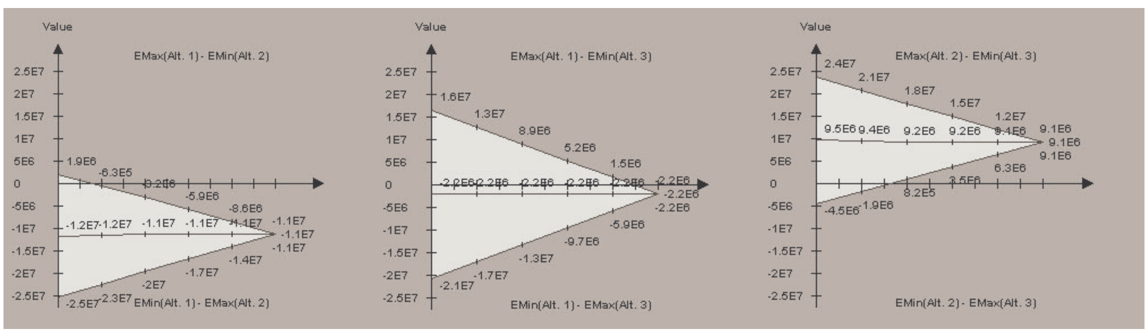

Figure 3.3: Evaluation of the UTB alternatives

The selection procedure then continues with:

(i) Remove all strongly dominated consequence sets

(ii) If more than one consequence set remains

(ii a) Cut the frame until only one consequence set remains

(ii b) Remove the markedly dominated consequence sets

(ii c) A combination of (ii a) and (ii b)

(iii) If only one consequence set remains

(iii a) Uncut the frame until other consequence sets appear

(iii b) Study the markedly dominated consequence sets

(iii c) A combination of (iii a) and (iii b)

Before a new iteration starts, alternatives found to be undesirable or obviously inferior by other information could be removed from the decision process. Likewise, a new alternative can be added, should the information gathered indicate the need for it. Consequences in an alternative can be added or removed as necessary to reflect changes in the model. Often a number of cycles are necessary to produce an interesting and reliable result.

3.2 ANALYSIS OF THE POLICY OPTIONS

Taking the simulation results into account the scenarios are analysed with the decision theoretical tool described in Section 3.1. This analysis incorporates the various costs, criteria and probabilities involved. For the evaluation of the options, the aggregated data in the tables 2-10 have been used.[1]

3.2.1 Modeling Impreciseness in Data

Of great importance here is that the frequency of floods and levee failures used in the described simulations are based on historical data. That is, for instance, they do not reflect the flood increase during recent years. For a number of years, the flood peaks have constantly increased. This may be a result of the change in the land use, for instance forest cutting, urbanization, asphalting and other changes of land use, or it could be a result of global climate changes (CLC 01). Anyway, adequate and precise information is missing to a large extent in the kinds of simulation models described above. Therefore, in the analyses below, ranges of values have been used instead of the values from the simulations. The ranges are 40% intervals centred around the table values as mid-points. Needless to say, this is an arbitrary estimate, but the setting could easily be changed.

3.2.1.1 Probability Estimates

Table 11 shows the used values for the probabilities. These are based on the corresponding values of table 2. In the table, the left value is the minimum value for the probability, and the right value is the maximum value. It should be noted that the values are adjusted such that all values of the intervals are feasible modulo the laws of probability, i.e., there must exist some vector of variable assignments that simultaneously satisfies each statement in the system.

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[1] The same principles could have been applied to the non-aggregated data in Appendix 5, but the result would basically be the same.

Min probability	Max probability
0,858	0,906
0,034	0,052
0,021	0,032
0,028	0,041
0,011	0,017

Table 11

3.2.1.2 Cost Estimates

Table 12 shows the interval costs. These are based on the values of Tables 2-10 above. Also here, the left value under each category is the minimum value (80% of the simulated value) for the outcome, and the right value is the maximum value (120% of the simulated value) for the outcome.

Government			Insurers			Pilot basin	
Scenario 1							
0	0		1821440	2732160		-1821440	-2732160
-7497940	-11246910		-3149140	-4723710		-14346053	-21519079
-97777985	-146666977		-43576094	-65364141		-184572538	-276858807
-181804104	-272706157		-76838038	-115257057		-347371539	-521057308
-635607429	-953411143		-250668160	-376002240		-1232415840	-1848623760
Scenario 2							
0	0		1975678	2963518		-1975678	-2963518
-3748970	-5623455		-3259728	-4889591		-17984435	-26976652
-48888992	-73333489		-25085495	-37628242		-251952130	-377928194
-90902052	-136353078		-45683626	-68525439		-469428003	-704142005
-317803714	-476705571		-169665550	-254498325		-1631222164	-2446833246
Scenario 3							
1771632	2657448		0	0		-1771632	-2657448
-5726308	-8589462		0	0		-19266825	-28900237
-96006353	-144009529		0	0		-229920264	-344880395
-180032472	-270048709		0	0		-425981209	-638971813
-633835797	-950753695		0	0		-1484855632	-2227283448

Table 12

3.2.2 Constructing the Decision Tree

The decision tree is constructed from the three policy scenarios, which are considered as alternatives in the tree. Each of these alternatives has the same set of probability nodes, i.e., the five outcomes with the respective probabilities from Table 11. The final outcomes of the five nodes are divided into the three categories: Government, Insurance industry, and Pilot basin. Figure 3.4 shows a sub tree for Scenario 1. For completeness, Appendix 6 shows the entire tree including all scenarios.

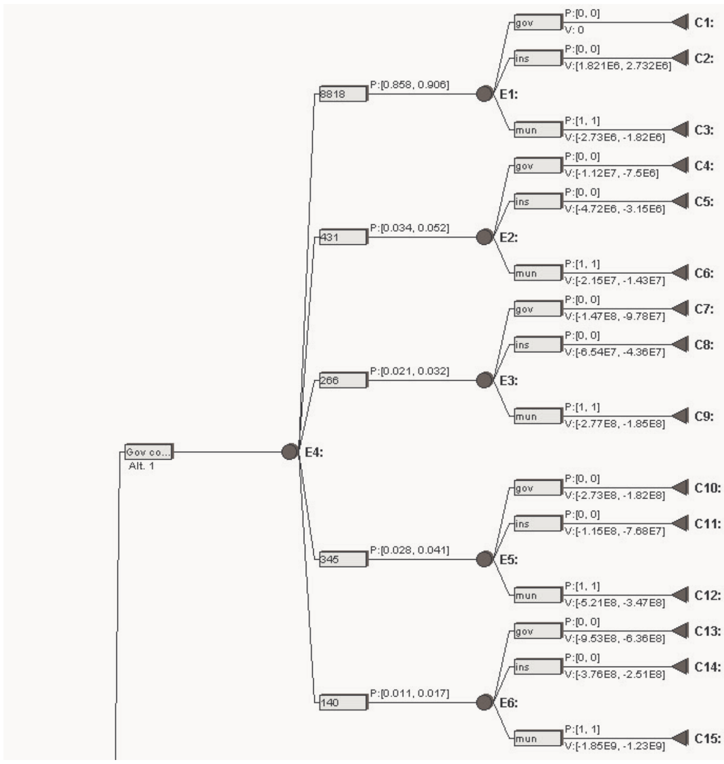

Figure 3.4

The values are mechanically entered into the tool, directly from the simulations. As was explained in Section 3.1, the weights of the stakeholders are modelled at the last level of the tree. The weights sum up to 1 for each of the probability nodes at the next-to-last level. As will be demonstrated in the following sections, the effects of manipulating the weights can then be easily analysed.

3.2.3 Analysing the Scenarios

The following analyses show the result of various evaluations of the decision situation. The following different assumptions have been tested:

- All stakeholders are equally weighted. This shows that the choice is solely a matter of ranking the stakeholders' relative importance.
- Each of the stakeholders is assigned the weight 1. This clearly shows different stakeholder preferences among scenarios.
- The government is considered to be more important than the municipalities.
- The municipalities are considered to be more important than the government.

The perspective of the insurance companies is not taken into account to a large extent in the analysis, even if this easily can be done. It was clear from the interviews (Appendix 2) that a situation where these are considered of most importance would not be publicly acceptable.

3.2.3.1 Equal Weights

It can be seen from Figure 3.5 that all scenarios are equal when the stakeholders receive the same weight, i.e., when all stakeholders are given the weight 1/3. An observation is therefore that to determine the preferred scenario, given the underlying data set, the choice of scenario is obviously a matter of determining the rank between the stakeholders.

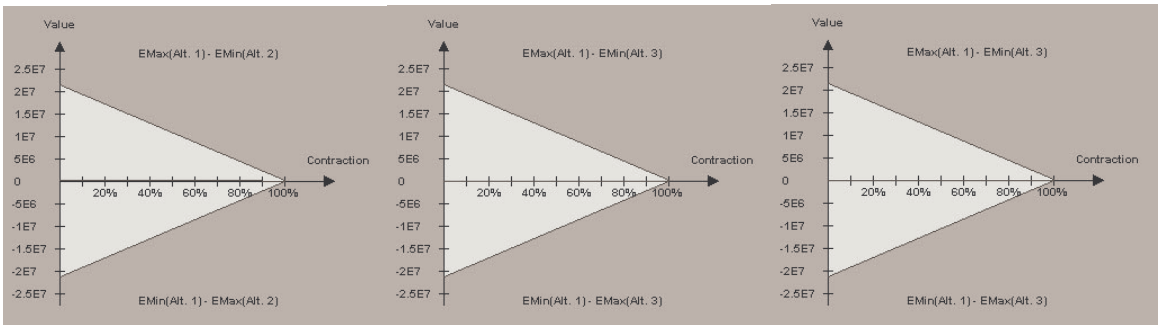

Figure 3.5 The stakeholders' weights are equal

3.2.3.2 Each Stakeholder Dominates

The figures 3.6 to 3.8 below show the results of the situations, when each respective stakeholder has the weight 1.

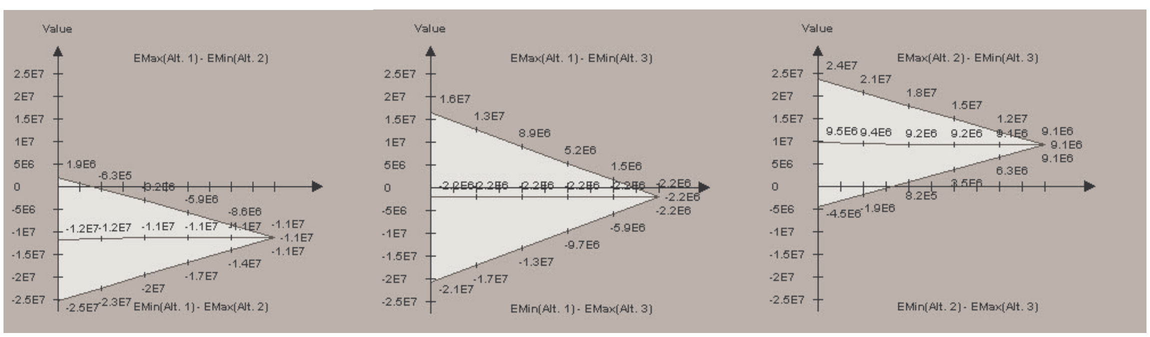

Figure 3.6 The weight of the government is 1

It can be seen from Figure 3.6 that, from the governmental perspective, Scenario 2 is considerably better than the others. Scenario 3 is slightly better than Scenario 1.

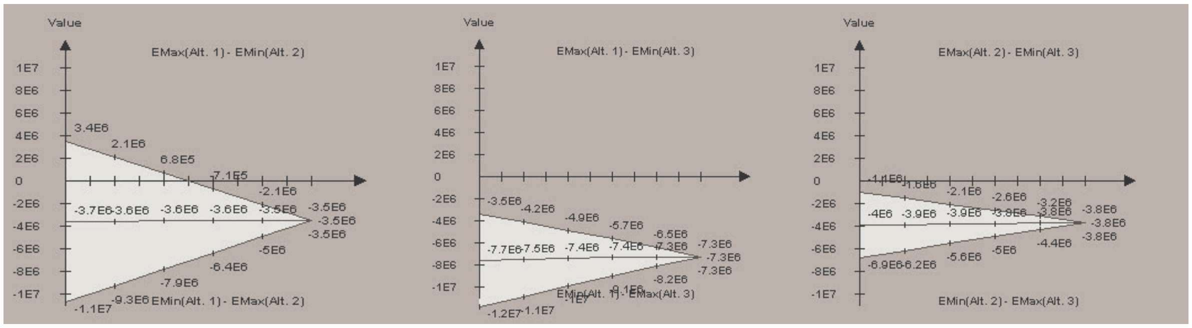

Figure 3.7 The weight of the insurance companies is 1

Figure 3.7 shows that, from the insurers perspective, Scenario 3 is considerably better than the others. Scenario 2 is clearly better than Scenario 1.

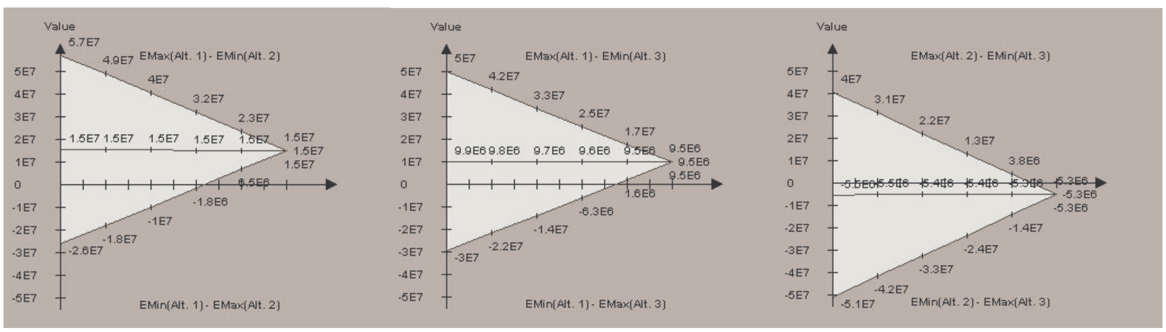

Figure 3.8 The weight of the municipalities is 1

Figure 3.8 shows that, from the perspective of the municipalities, Scenario 1 is better than the others. Scenario 3 is slightly better than Scenario 2.

3.2.3.3 Ranking the Stakeholders

Figure 3.9 shows the analysis when the weight of the government is greater than the weight of the municipalities. Both these weights are greater than the weight of the insurance companies. It can be seen from the figure that Scenario 2 is the most preferred, followed by Scenario 1.

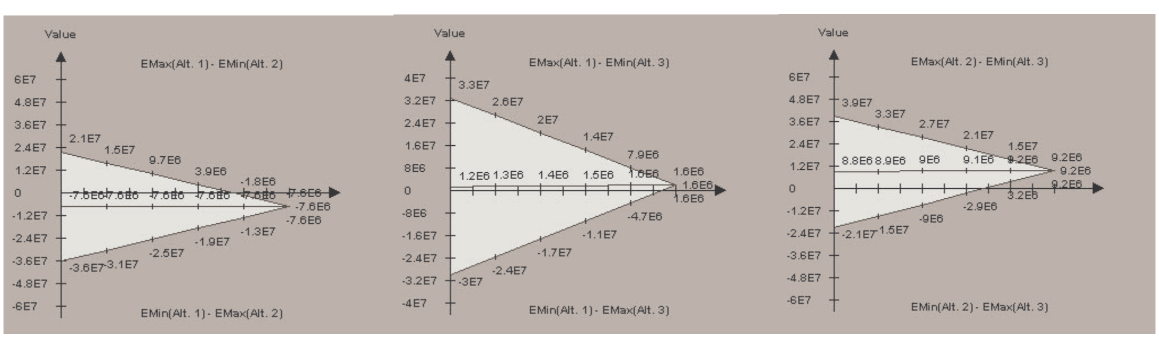

Figure 3.9 Weight of government greater than municipalities

Figure 3.10 shows the analysis when the weight of the municipalities is greater than the weight of the government. As in the previous analysis, both these weights are greater than the weight of the insurance companies. It can be seen from the figure that Scenario 1 clearly is the most preferred, followed by Scenario 3.

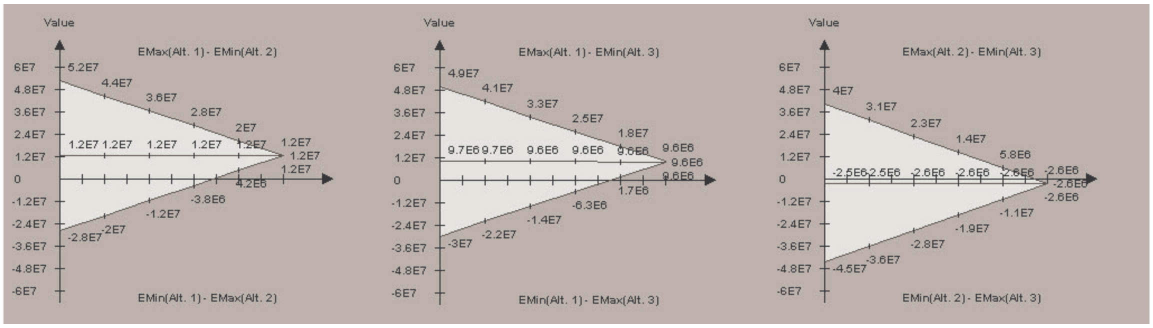

Figure 3.10 Weight of municipalities greater than government

3.2.3.4 Conclusions

The conclusions of these analyses, when only financial losses are taken into account, are the following:

- The choice is a matter of ranking the stakeholders' relative importance.
- From a governmental perspective, Scenario 2 is preferred.
- From the perspective of the insurance companies, Scenario 3 is preferred.
- From the perspective of the municipalities, Scenario 1 is preferred.
- When the government is considered to be more important than the municipalities, Scenario 2 is the most preferred option.
- When the municipalities are considered to be of more importance than the government, Scenario 1 is the most preferred option.

4. INTERVIEW RESULTS

The seven semi-structured interviews were based on an interview protocol (Appendix 1), and the respondents did receive this in advance. The protocol served as a base for the interviews and we also used a probing technique, whenever it was necessary in order to get out more information from the respondents. Each interview lasted between 2 and 3 hours. The participants in the study where not randomly chosen. Instead the selection aimed at securing a broad spectrum of stakeholders.

Strikingly, all local interviewees agreed that people should be able to stay in high-risk areas, and there seems to be more agreement regarding the goals and assumptions than means to achieve these goals. Various reasons are mentioned, e.g., it is more cost-effective than to move people. Furthermore, poor people cannot survive in more expensive areas and most of them have a low standard of education. In the Upper Tisza basin, people can survive on limited resources, e.g., there is no monthly cost for central heating, a cost that is mandatory for apartments in the cities. From the low income perspective, people can have reasonable lives in the upper Tisza basin, which would not be possible in the cities.

One of the locals said that, “otherwise the whole country should pay for their moving and this would probably be much more expensive”. A local also stressed the fact that if it would be possible for people to stay in a catastrophe-hit region, the system must take into account the indirect losses to the economy and jobs, not only the reconstruction of the dwellings. For example, in the recent Bereg case, when losses to agriculture and other businesses have not been compensated, it is very likely that people will not be able to maintain and operate their beautiful new houses – e.g., they will turn off the gas heating and heat with wood again, etc.

Another local, however, said that there are areas, which must be given up for economic reasons. He also stated that there are limits to economic irrationality; for example, in an extreme case we are protecting 5 billion HUF value with a 30 billion HUF investment.

Others also think that maybe this area cannot maintain all these people, but most agree that *the issue of regional development should be separated (at least politically) from the catastrophe management and compensation issue.*

Assumption 1: All locals emphasize that this is a very poor and backward area. Most people cannot recover without help. If their homes are washed away, most need 100% compensation.

Assumption 2: All locals think that the government has to take responsibility for catastrophes occurring as a result of failure in the primary defence lines. This is because the state has full responsibility in maintaining these lines. Some think that this responsibility should be 100%.

Assumption 3: Mitigation is more cost-effective than loss sharing. The flood risk can and should be decreased (The so called “New Vasarhely iterv” which is currently planned, will reduce the risk significantly. Its estimated cost would amount about less that 100 billion HUF. Implementing this plan is certainly more cost-effective that paying insurance premiums).

Tools: For the above reasons, tools of solidarity are much more emphasized than market-based elements.

All interviewees agree that the recent system has problem, in particular, its unpredictable nature disturbs people. For example, an official of the national disaster management authority said that after the 2001 flood, the government compensated all property owners, even the households who had private flood insurance. When floods happened earlier (1999 and 2000), the governmental compensation-procedure looked different, because the insurance compensation was then deducted from what was compensated by the government. However, the last flood was considered to be the responsibility of the government, as it was a primary levee that burst (earlier this was not the case). Furthermore, political considerations were made – if the governmental compensation was reduced this time, nobody would buy private flood insurance in the future. Furthermore, some people criticize the fact that people can make money from a catastrophe.

An officer of the regional water management authority gave an example on the latter and said that it is not desirable that people get more than 100% compensation in total. He added that this is a problem with Scenario 1 – because those who have insurance can receive more than 100%. In an extreme case, they can damage their houses – as it really happened in 2001.

Insurance is preferred by locals in the Scenario 3 *non-profit, cross-subsidised form* (which is regarded as a "government insurance" or a catastrophe tax). The idea of a catastrophe fund (similar to the concept of national pool, proposed by (Mitchell 01)), which cannot be used for other purposes, is also supported by most interviewees. (Note that there was such a fund earlier, but the government wanted "free hands" to use it. Therefore, all separated funds were merged in the budget. Separate funds are in contradiction with current centralizing tendencies).

Thus, locals mainly support cross-subsidised premiums, in contrast to the representative of the insurance industry who strongly supports risk-based premiums. However, some would add risk-based premiums for property owners who want to receive more compensation (e.g., the more affluent), or those having summer houses, etc. Furthermore, all locals agree that the government should pay – or at least contribute to - the premiums for people who are poor and cannot pay them by themselves. There are some who claim that the government should pay – or contribute to – the premiums for all properties which are located in high-risk regions.

Mandatory insurance seems to be supported by most locals, but the representative of the insurance industry is very much against it and thinks that it is infeasible. The representative of the Association of Hungarian Insurers, said for instance that, "Mandatory insurance raises bad memories in Hungary – people do not like things that are mandatory".

Most locals think that in case of a large disaster, compensation – paid by the government or by the catastrophe fund - should be 100%. There is one person who would decrease the compensation and add elements, which should encourage people to move. Such elements would be either interest-free loans, or risk-based insurance - a version of Scenario 2. (Note that both would work only for people who are not poor). One of the local mayors mentioned for instance that once when there was a flood, only 100 persons, (out of 1600 persons in the village, and out of 900 in active age), received the loans. The reason was that a term for the loan was that people must have been employed for at least a year. Consequently, the poor would not move anyway – they should be compensated, or their risk-based premiums should be paid.

Most locals do not have strong feelings about government reinsurance, although some are strongly against it (assumption: insurance companies can buy it on the international market). The representative of the insurance industry strongly supports it.

The information below (figures regarding the last flood in the upper Bereg basin) provides us with real data which is valuable when evaluating different insurance scenarios and different ways of compensating losses. The following data are based on the interview with an official of the national disaster management authority:

The reconstruction costs were initially estimated to 25.000 HUF/m2; this figure was finally adjusted upwards to 100.000 HUF/m2. The first estimate of the damages in the Bereg basin was that the direct losses (private households only) summed up to 5 billion HUF (direct losses). Finally, the losses were estimated to 15 billion HUF (this is what government paid, plus insurance companies paid 2,8 billion HUF. The large difference shows that government compensation may have been too generous). If buildings belonging to the central government, crop damages, damages in public infrastructure, etc. are included, the total losses sum up to 50 billion HUF.

There are, however three explanations to why the initial estimation of the losses was much lower than the final figures.

1. The damages of adobe houses are revealed in different time steps; direct damages appear immediately after the flood. Secondary damages appear when the house dries up; these can be cracks in the walls etc.
2. People who made the first estimates were not real experts. If insurance companies had made it, estimates would have been much closer to real costs. In addition, first estimates were made at the time of flood protection.
3. Reconstruction costs were much larger than what was originally expected. A consortium consisting of five construction companies was assigned the task of reconstructing the damaged houses.

The government offered following compensation alternatives after the last flood (Bereg basin):

1. The property owner receives a new house in the same location, built in a material better suited to stand future floods (concrete house, standing on a 1,5 meter high foundation – this flood was about 1 meter high). Applied for: Severely damaged houses (destroyed).
2. The house is renovated on the expense of the government. Applied for: Moderately damaged houses.
3. The property owners could choose to leave the basin and buy a house of similar standard in other municipalities (but only within the county), with less flood risk. The old damaged house was then taken down. The government paid for the new house, controls were made to assure that the new house was of similar standard etc. Applied for: Severely damaged houses (destroyed) and for moderately damaged houses.
4. The property owners were given cash economic compensation; the size of the compensation handed out was lower than renovation costs for the house (25 000 HUF/m2 for adobe house, 50 000 HUF/m2 for non-adobe house).
5. One restriction that was introduced was that people who received new houses must not sell them for 15 years.

Since 206 people bought other houses, demand and real estate prices went up. (However, the market value of the new houses is still about the half of the reconstruction costs.) People have to spend much more money for the utility fees in these large, new houses (e.g., gas central heating, closed septic tanks – technically better solutions, but expensive). The property owners with damaged houses made the following choices (based on 98 % of the households):

- 766 house owners received a new house on the same location
- 1719 house owners had their homes renovated
- 206 house owners choose to move out
- 183 house owners received cash economical compensation

Regarding the insurance options, according to the interviewee the third scenario is preferred, but without making the fee mandatory (since this would be infeasible anyway, he said). The government should help to make insurance more attractive (for example, insurance fees could be deducted from tax). It would be desirable that more people have insurance. Currently, insurance companies pay 1% of their profit (1,5 billion HUF in total) to the government. This money is used for fire protection purposes. Such system could be extended to natural catastrophes. Catastrophe funds would be a good idea. It has existed before.

5. CONCLUSIONS

Based on earlier interviews performed in the Palad-Csecsei basin (Vari 01, 01b), this report discusses three alternative flood management policy strategies. We have investigated the effects of imposing these for the purpose of illuminating significant effects of adopting different insurance policies. The main focus has been on insurance schemes in combination with level of governmental compensation.

The analyses of the different policy strategies have been based on a model where the flood failures are simulated and where geographical, hydrological, social, and institutional data have been taken into account. The generated results are thereafter automatically transposed to decision trees under three stakeholder perspectives. Thus, taking the simulation results into account, the scenarios have been analysed with a decision theoretical tool for evaluating the various costs, criteria and probabilities involved.

However, of great importance here is that the frequency of floods and levee failures used in the described simulations are based on historical data and does not, for instance, reflect recent years increase of flood peaks. In general, these kinds of simulations, dependent of quite a large number of input data, are also very sensitive to various types of errors. Consequently, there seem to be significant reasons for discriminating between measurable and immeasurable uncertainty in this context. Since an actual and precise uncertainty measure is lacking, the simulations have been used merely as a basis for a more elaborate sensitivity analysis, considering both probabilities for floods and the estimates of losses.

We have also, to some extent, validated the approaches using stakeholder interviews. A main issue is that all local interviewees think that people should be able to stay in high-risk areas, and there seems to be more agreement regarding goals and assumptions than means to achieve these goals. This motivated the entire scenario construction approach. Furthermore, it was emphasized that tools of solidarity are much more emphasized than market-based elements. This was the motivation in selecting the criteria for the analyses.

It should be noted that we have refrained from making any definite conclusions as to which of the three policy scenarios is the best; the preferences concerning level of solidarity/private responsibility is the single most important perspective that affect this choice.

In the next phase, a stakeholder workshop will be conducted where the stakeholders can debate and promote the different policy strategies. The stakeholder workshop will take place during September 2002. Other activities within the research project are also to scale up the results of the pilot basin to the entire county. More policy strategies are being identified and implemented, for instance re-naturalization by taking down sections of the levee upstream the villages. This step is quite controversial, since much arable land would be sacrificed to save the villages. It can also be seen as a more holistic flood management strategy; floods are really a natural part of the riverine system.

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LIST OF APPENDICES

APPENDIX 1: INTERVIEW PROTOCOL

TISZA River Interview Guide

<u>OPTIONAL INTRO:</u> The project "Flood Risk Management Policy in the Upper Tisza Basin: A System Analytical Approach" is an international research project with collaborators from Austria, Hungary, and Sweden. The project is funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning. The research project is aimed at understanding the flood risk management problem in the Upper Tisza region.

The background information for this study is provided in the attached documents and the suggested decision trees for choosing insurance policies and mitigation measures are also provided.

We would like to take this opportunity to point out that all your responses will be treated in the strictest confidence. None of your responses will be directly attributed to you or to your institution.

A. PROLOGUE

1) Which flood related areas do you deal with, or responsible for?

2) How did you get to be in this position?

- *Academic/professional background*
- *Career path*

B. IMPORTANCE OF DIFFERENT AGENTS

1) What is your view on how flood insurance and mitigation policies should be handled?

- *The flood-fighting approaches should focus on "top-down" decision-making*
- *The success of future mitigation strategies will depend on putting some control in the hands of the communities.*
- *Other*

2) **Please rank the following with respect to responsibility for compensating flood losses.**

- *The Hungarian government*
- *The local/municipal governments*
- *Property owners*
- *The upstream countries*
- *Insurance companies*
- *Other*

3) **Who are the most important actors to involve when formulating and implementing insurance and mitigation policies? Rank the following with respect to importance.**

- *State actors (ministries, civil servants, executive agencies, etc.)*
- *Political actors (ministers, advisers, spokespersons of political parties)*
- *Interest representation and NGOs (environmental groups, specialised interest groups, etc.)*
- *Private sector actors (insurance companies, banks, firms, etc.)*
- *Research actors (universities, think-tanks, research organisations, etc.)*
- *Property owners*
- *Others*

4) **In general, who do you consider to be the most trustworthy for evaluating flood losses and mitigation measures? Rank the following.**

- *Experts of water management*
- *Experts of municipal governments*
- *Experts of the Hungarian government*
- *University teachers and researchers*
- *Experts of the Hungarian Academy of Sciences*
- *Experts of international intergovernmental organizations (e.g., E.U.)*
- *NGOs and environmental group experts*
- *Other*

C. INSURANCE POLICIES

C1. CONSEQUENCE STRUCTURE

1) **Demonstration and discussion of a tentative decision tree with probability and value estimates.**

2) **In the document provided, a consequence tree is suggested. Please modify this tree according to your perception of events that may occur as consequences of major floods. You may want to consider categories like the following.**

- *Roads, utilities, and public buildings are damaged*
- *Farming activities become impossible*
- *Homes, summer houses are damaged*
- *The income from farming activities becomes highly uncertain*
- *People get distressed, and often become ill*
- *Property values decrease in the endangered areas*
- *Strain on families removed from their home environments*
- *Altered social relationships*
- *Personal vulnerability and loss of control*
- *Other*

C2. VALUE ESTIMATION

1) **Please estimate the consequences in the finalised tree with respect to values. If possible, try to estimate the values precisely, in intervals, or by just ordering them. You may want to consider categories like the following.**

- *Distribution of costs, i.e., the risk groups pay for their costs vs. taxpayers in low-risk areas subsidise those in high-risk areas*
- *The possibility that large groups cannot afford to pay insurance premiums*
- *Separate treatment of owners of vacation homes or well-to-do businesses*
- *Less consideration of victims who have built their homes in high-risk areas without a permit*
- *Encouragement of neighbors and others to help one another*
- *Villages should be protected at all costs*
- *Insurance companies may go bankrupt after a very serious flood*

2) Could you see any activities that reduce the severity of the consequences? If this is the case, how does it affect the decision tree? You may want to consider categories like the following.

- *Take into consideration particularly vulnerable groups*
- *Take into consideration critical aquatic life and wildlife habitat vulnerable to damage from flooding*
- *Consideration of options to protect better the basin from contaminants during future floods*
- *Consideration of options to protect critical habitat*
- *Conversion of marginal agricultural land of the floodplain into a greenway, park, forest preserve or other use not subject to much damage*
- *Tightening zoning ordinances to restrict the kinds of development permitted in flood-prone areas.*
- *Information available to individuals, government, and non-government organizations and others gathered and made available at a central basin-wide archive or archives*
- *Possible compensation for villagers choosing to relocate*
- *Low-income persons are assisted in purchasing insurance*
- *Property owners taking more responsibility*
- *Insurance companies assisting governments in building flood defences*
- *Insurance companies might not insure poor persons living in very high risk areas*
- *Insurance companies might not insure all flood risks*
- *Insurers charge the same insurance premium for people living in low-risk areas*

C3. PROBABILITY ESTIMATION

1) Please estimate the consequences in the finalised tree with respect to probabilities. If possible, try to estimate the values precisely or by using intervals.

2) Could you see any activities that change the probabilities of the consequences? If this is the case, how do they affect the tree? You may want to consider categories like the following.

- *Developing or improving arrangements for warning of imminent flooding*
- *Developing or improving flood preparedness plans*

- *Working with governmental or local agencies to provide or improve structural protection for the area*
- *Providing technical and/or financial assistance to property owners in flood proofing or otherwise protecting their property against flooding*
- *Establish sufficient information centres prior to and during a flood event*
- *Better organised decision management at central and local governments*

D. MITIGATION MEASURES

D1. CONSEQUENCE STRUCTURE

1) **Demonstration and discussion of a tentative decision tree with probability and value estimates.**
2) **In the document provided, a consequence tree is suggested. Please modify the tree according to your perception of events that may occur as consequences of major floods. You may want to consider categories like the following.**

- *Roads, utilities, and public buildings are damaged*
- *Farming activities become impossible*
- *Homes, summer houses are damaged*
- *The income from farming activities becomes highly uncertain*
- *People get distressed, and often become ill*
- *Property values decrease in the endangered areas*
- *Pollution is spread by flood waters*
- *Drinking water reserves become polluted*
- *Tourism is decreased*
- *The ecosystem becomes unbalanced or damaged*
- *Wildlife and vegetation is damaged*
- *Strain on families removed from their home environments*
- *Altered social relationships*
- *Personal vulnerability and loss of control*
- *Other*

D2. VALUE ESTIMATION

1) **Please estimate the consequences in the finalised tree with respect to values. If possible, try to estimate the values precisely, in intervals, or by just ordering them. You may want to consider categories like the following.**

- *Distribution of costs, i.e., the risk groups pay for their costs vs. solidarity*: taxpayers in low-risk areas to support those in high-risk areas
- *Large groups cannot afford to pay insurance premiums*
- *Separate treatment of owners of vacation homes or well-to-do businesses*
- *Special consideration of victims who have built their homes in high-risk areas without a permit*
- *Encouragement for neighbours and others to help one another*
- *Villages should be protected at all costs*
- *Insurance companies may go bankrupt after a very serious flood*
- *Other*

2) **Could you see any activities that reduce the severity of the consequences? If this is the case, how does it affect the tree? You may want to consider categories like the following.**

- *Compensation for villagers choosing to relocate*
- *Low-income persons are assisted in purchasing insurance*
- *Each jurisdiction with responsibilities for evacuation within the basin establishes an evacuation protocol within its emergency operation plan*
- *Clarity and public dissemination of the protocols to help prevent confusion at the time of evacuation*
- *Plans take into consideration the specific requirements of vulnerable groups, such as nursing home residents*

D3. PROBABILITY ESTIMATION

1) **Estimate the consequences in the finalised tree with respect to probabilities. If possible, try to estimate their values precisely or by in intervals.**

2) **Could you see any activities that change the probabilities of the consequences? If this is the case, how does it affect the tree?**

Thank the respondent and Close

APPENDIX 2: INTERVIEWS

Officer of the Upper Tisza Reginal Water Authority
26 February, 2002

Goal/1: We do not want that people make a profit from a catastrophe. This means that it is not desirable that people get more than 100% compensation in total. This is a problem with Scenario 1 – because those who have insurance can receive more than 100%. In an extreme case they can damage their houses - as it really happened in 2001.

Goal/2: We want to keep people in risky areas. Otherwise the whole country would have to pay for them moving and this would probably be much more expensive. Therefore, we have to help people in high-risk areas to recover after major floods.

Goal/3: The overall risk should be decreased. Houses should be built in safer locations, with better technologies.

Considering the above goals, Scenarios 1 and 3 both have large solidarity elements, while Scenario 2 is more market oriented and it would lead to an outmigration from high-risk areas (because of less than 100% compensation and high risk-based premia). Scenario 3 is somewhat better than the other because 100% compensation can be assured, and in addition, damages do not have to be estimated and paid via two channels, insurance experts can be used to estimate the damages.

At the same time, mechanisms are needed that would make people interested in decreasing the damages. For example, building permits should not be issued for deep areas which are frequently flood by seepage from river or standing water from precipitation. Another solution: existing houses demolished and people moved to "social" apartments. This happens in Belgium.

To reach the above goals, the interviewee combined the various scenarios and proposed the following two alternative policies:

A. Modified version of Scenario 3: Mandatory insurance, with less than 100% compensation, and government support to the poor by paying the premia. To start all over in case of a large catastrophe an interest-free loan is offered. It can be used to build new houses in less risky locations with more advanced technologies.

B. Modified version of Scenario 2: Three pillars where the first two pillars add up to 100%, plus risk-based insurance can be bought as well. The poors get their premia paid by the government.

The interviewee suggested that discharge data for the 100 years and 1000 years flood should be considered with caution because they are very uncertain. Sensitivity analysis were proposed where both discharge and probability data could be manipulated.

Mayor of a city in the Bereg region
February 27, 2002

Scenario 1: It is basically OK. Protecting the people from flood is the responsibility of the government. Therefore he thinks that *100% government compensation* in case of a dyke failure is fair and it is government responsibility. In addition, people who have insurance should be compensated by the insurance companies. In previous years, insurance was deducted from the government compensation, but this sent a wrong message to those who insured their homes.

He talked about the anomalies of the property values – the market values of the old houses were about 1-2 MFt, but if the government had paid this amount, people would not have been able to rebuild their houses. New houses were built for 8-10 MFt, but if somebody would like to sell them, they would be worth 3-4 MFt. Differences are less in the city, but larger in the small settlements.

Scenario 2: Government has either to guarantee 100% compensation, or *help paying insurance* premia to the insurance companies on behalf of the inhabitants of the high-risk regions. But he cannot support the option where government pays premia for households in low-risk areas. According to him the government should pay (fully or partially) the premia for people living in high-risk regions, because government is responsible for protecting such areas. (NOTE: This makes sense only if premia are risk-based, otherwise people living in low-risk areas have to pay more than people living in high-risk areas, which is nonsense!)

He also spoke about the premia received by insurance companies. For AEGON (the largest insurer) the yearly total premia in the Bereg region is 200 MFt. In 2001 they had to pay 1,5 billion Ft for the damages which occured in Bereg. In January 2002 they started to pull out, and cancelled the flood-insurance from 12 000 contracts in the Upper and Mid-Tisza flood basins. (The other six companies operating in the region paid 1,3 billion Ft in total in 2001. Most of them are willing to offer flood-coverage, although with some restrictions, e.g., some companies do not want to cover adobe houses which have no foundations).

He concluded that mitigation is cheaper than loss sharing. The so called „New Vasarhelyi-terv" which is currently planned, will reduce the risk significantly, and its estimated cost would amount to less than 100 billion Ft. Implementing this plan is certainly more cost-effective than paying insurance premia

Scenario 3: He could support scenario 3 if Government paid premia in high-risk regions (see above), and if some of the risk was taken by the insurance companies – like in the French system, but he *does not think that government reinsurance would be necessary*, because small companies can find reinsurance at large companies.

Mayor of a village in the Szatmar area
27 February, 2002

The heavy metal pollution that occurred only weeks after the cyanide spill, does still have large impact on the tourism industry in the region. The water tourism (boating, canoeing, etc.) still visits the area, but the stays are shorter then before. Elderly people used to spend the entire summer there, but this doesn't happen any longer. The amount of fish has been affected; even tough this part of the river was not contaminated by the cyanide spill. The heavy metal spill, that did pollute this part of the river, did not kill the fish. As the fish was reduced upstream, in the Samos tributary, many anglers and fishers moved to this part of the river instead. Fish implantations were not made in this part of the river.

Scenario three seemed interesting according to the interviewee, but he identified a number of potential problems:

1. Some people can benefit from the floods, by getting new houses from the government. The system must assure that the compensation is limited so no overcompensation can happen. If a new house is built it should have a standard similar to the old one.
2. Even the 40 per cent that are not considered 'low-income household' could need subsidised premiums. He did not think that private responsibility needed to be encouraged. Households should pay according to their economical situation, but still take responsibility.

Insurance Companies

The insurer (Aegon) that pulled back recently did only have a number of contracts in the region. The other insurers (3) are still active in the region. The price of the premiums depends on the material of the house (concrete, wood, clay, etc.). The location of the building does not make any difference in the size of the premium, they are not risk-differentiating within the Tisza river basin. In general, adobe houses are three times as expensive to insure as concrete houses. Adobe houses are old-fashioned and built by clay-bricks.

Interest-free Loans

Out of 1600 persons in the village (900 in active age), only 100 received the loans, one term for the loan is to have been employed for at least one year.

Re-location

Many of the people are low-educated, which would make the re-location alternative very costly, as it would lead to unemployment. In this Upper Tisza basin, people can live and survive on very little money. There is no monthly cost for central heating for instance, a cost that is connected with apartments in the cities. From the low incomes, people can lead reasonable lives in the upper Tisza basin, which would not be possible in the cities.

Unemployment

Neither tourism nor agriculture is enough for anybody to live on.

Tourism

The tourist-season only lasts two months a year: Some restaurant-owners try to survive the rest of the year by preparing food for schools and companies, but it is difficult. They cannot afford to renovate the their buildings.

Agriculture

The production in this area is not high, but it is not very low either. Especially the fruit production is quite reasonable. The problem is that the farmers are unable to sell their fruit and vegetables since they don’t cooperate with any larger chains. The distribution-channels are still under-developed, which leads to those large amounts of fruit and vegetable rot that cannot be sold to the cities. Due to distribution problems and uncertainties regarding the price-levels for different crops, many farmers choose not to cultivate their land or to recreate the live-stocks (?).

Director of a regional Environmental NGO
February 28, 2002

Goal: People should not leave the area, but of course, there are areas which must be given up for economic reasons. There are limits to economic irrationality, for example, in an extreme case we are protecting 5 billion Ft value with a 30 billion Ft investment.

Scenario 1: The most important is to change the current system. There are a lot of uncertainties in the current system. The insurance system is problematic as well, but government compensation is even more problematic because it is completely unpredictable. Another problem is that buildings are strongly under-insured.

Scenario 2: Government has to play a role, because people cannot pay high risk-based insurance premia in the high-risk regions.

Scenario 3: Cat-fund is a good idea, but it should not be operated by a government authority. I do not prefer large government bureaucracies, rather a profit-oriented organization should operate it. Certainly these funds should not be located in a ministry.

If the insurance companies run the system, it will be more effective – private business is more profit-oriented and rational, chance of corruption is much smaller than in the government sector.

Mandatory insurance is problematic, people would not be willing to pay it. Cat-fund is a good idea, but I do not see how it could be collected. It could be collected as a tax, but I am not sure that there will be a political will for this. Another option would be to get insurance companies to collect it. For people who cannot pay premia, the government should pay them.

This would be a good business for the insurance companies, therefore their duties should be much more clearly regulated. Insurance should pay for seepage, standing water, etc. if it is related to riverine floods. And this system would be good for the government because they could get rid of the risk.

On the other hand, regulations should guarantee that houses are built with appropriate technologies, so they wouldn´t get to damaged. Regulation and control should be more stringent. Authorities can do a lot, but individuals cannot do much to decrease the losses.

This system should first be built up for private residences, but later they should be extended for community properties, and also private businesses (jobs are erased by the flood!).

Recently premia were raised severely. In the Upper Tisza they doubled. But still, it is crucial that buildings should not be under-insured. If they are under-insured, it is impossible to reconstruct the buildings from the compensation. Risk-based premia would be too high for the people, but if the govt. has to pay it, that is efficient, because they have to decide if they should pay higher premia, or protect the region.

Risk-based premia should be applied on the level of settlements, then people would move to higher points. But the reality is that people cannot leave the whole Bereg area behind.

If people cannot pay the high risk-based premia in high-risk areas, they would move, but this is not necessarily good. He would not propose to young people not to move there, because then only the old and the Roma population would stay there, because they cannot sell their houses, or if they could sell them, they would not get much out of it. The situation would get worse and worse.

However, there should – and will – be major changes. Soil is not good for agricultural production. Also, the EU accession means that less land will be used for agricultural production. Agro-land could be reduced and wetland be created. This would be good for mitigation.

150 years ago it was possible to pass a long area by canoeing on the streams, not only on the Tisza. There was a large wetland there. In the Hortobagy National Park, there are large areas which can be turned into wetlands. In these large unpopulated areas it is easier than in the Upper Tisza region where there are many small settlements near the river. When deciding about renaturalization, many factors have to be taken into consideration.

Advantages of complex land-use: not only ecological, but also economical. Intensive production 100 000 Ft/ha, complex use: 4-500 000 Ft/ha estimated income!! But changes from intensive use to complex land-use will be slow and gradual.

Representative of the Szabolcs-Szatmar-Bereg County Chamber of Agriculture
February 28, 2002

Goal: The system should make it possible to people in a catastrophe-hit region to be able to recover. If people are not able to start all over again – especially in a case of a large damage concentrated to one region - then life there will be impossible. Moreover, it is not only the dwellings that should be important, because there are indirect losses to economy and jobs, these should also get reconstructed. For example, in the recent Bereg case, where losses to agriculture and other businesses have not been compensated, it is very likely that people will not be able to maintain and operate their beautiful new houses – e.g., they will turn off the gas heating and heat with wood again, etc.

Scenario 3 preferred. Proposed change: 100% compensation – indirect losses are still a severe load on the communities. The reason for this proposal is the poor situation, the high level of unemployment, and the bad quality of land in this county. Therefore, people do not have sufficient reserves, and in case of a catastrophe they cannot recover without external help.

The cat-fund is a good solution. The organization which handles the cat-fund should work on a non-profit basis. The government should pay at least 90-95% to the insureds that are poor. Such a fund should have been created a long time ago.

What kind of premia? He does not agree with risk-based premia, he would support cross-financing. If such a catastrophe-insurance is mandatory, it is like a property-tax. For poor people this tax is waived, or paid by the government. And it should be broader than just flood, it should cover various catastrophes. But the fund covers only homes, not *summer houses (these should be insured on the private insurance market).*

Reinsurance by government: AEGON would like government reinsurance because they have problems on the international reinsurance market. He has no opinion on this issue.

Q: But should people be encouraged by the compensation to stay here and build homes over and over again?

R: If we want people to leave that should not be tied with decisions on compensation. These two issues should be kept separated. Regional development decisions should be made by the government for long-term, and it should be decided what kind of activities should be encouraged, and how many people should stay. For example, there is an increasing emphasis on multi-functional land-use, e.g., maintenance of pastures, forests, wetlands, recreation, as opposed to production by itself. The question is how many people should be involved in these activities, how should they be compensated for the decreased production, where should the others go? And if we want that some of them leave, they should receive some funding for this. In case of floods, they should be able to receive money as compensation and move. Young people have started to move anyway.

The Socialist Party's program includes the idea of a catastrophe fund and that this concept should be developed. They are also working on a fund that should cover agricultural losses. Recently this is uninsurable loss (agricultural flood-loss).

Representative of the Association of Hungarian Insurers
March 1, 2002

Recent events: AEGON is pulling out from flood insurance in the risky area. The main reason for this is the difficulty of finding reinsurance for catastrophe risks. Other 8 companies are replacing AEGON which for the time being have no such problems (they have less contracts in the property insurance field).

Evaluation of the various solutions:

Scenario 1: If business as usual continues, other insurance companies will be likely to pull out. To prevent these, premia have to be raised significantly in high-risk areas.

Scenario 2: *Risk-based insurance* is a good idea, he would like to see it more. In high-risk areas premia could be one magnitude higher than now, the government should *pay the difference between cross-financed premia and risk-based premia for the insurers*. (This could mean in an extreme case that government pays 100% of flood insurance premia for *all people* living in high-risk areas which is financially equivalent with 100% compensation after floods).

Scenario 3: *Mandatory insurance* raises bad memories in Hungary – people do not like things that are mandatory. This kind of mandatory insurance does not exist in Europe – except for France.

Cat-fund would be a good idea, but he assumes that it will be accumulated from insurance taxes (3-4-5%), which have been proposed already three times. (The interviewee talked about insurance tax, a top-tax that is added on top of the premia.) This would not be fair because people who have already insured themselves would need to pay additional tax i.e., payments will be distributed among the insured rather than among all taxpayers. This may also make many people to cancel their insurance .

The amount of compensation paid to clients is always the reconstruction cost. If a low-standard house, an adobe house for instance, is destroyed, then it is compensated by a house of the same size but of a higher standard. This explains why the compensation is larger than the original property value of the house.

Under-insured houses are only compensated to certain per cent of it reconstruction cost. Wether a house is under-insured or not, if yes to what degree, is based on how large the coverage is, the insurance companies have records on the property values for all clients.

The cost for rebuilding of houses (from last flood of 2001) was 10 – 12 million HUF, but the market value of the new houses was only 5 – 6 million HUF.

Insurance contracts for adobe houses were cancelled from January 1st. This was said to have happened to 10 000 households. The government intervened with OTP and ordered them to offer flood insurance. The OTP wanted to keep the customers but get rid of the flood insurance.

Important info: There are about 7 million property insurance contracts in Hungary:

Administration and profit amounts cca. 30-35% of price.

Officer of the Ministry of Interior National Directorate General for Disaster Management
March 1, 2002

Figures from the last flood:

The reconstruction costs were initially estimated to 25 000 HUF/m2; this figure was finally adjusted upwards to 100 000 HUF/m2.

The first estimation of the damages in the Bereg basin was that the direct losses (private households only) summed up to 5 billion HUF (direct losses). Finally, the losses were estimated to 15 billion HUF (this is what government paid, plus insurance companies paid 2.8 billion HUF. The large difference shows that government compensation may have been too generous). If buildings belonging to the central government, crop damages, damages in public infrastructure, etc. are included, the total losses sum up to 50 billion HUF.

There are three explanations to why the initial estimation of the losses was much lower than the final figures.

4. The damages of adobe houses are revealed in different time steps; direct damages show immediately after the flood. Secondary damages show when the house dries up, these can be cracks in the walls etc.
5. People who made the first estimates were not real experts. If insurance companies had made it, estimates would have been much closer to real costs. In addition, first estimates were made at the time of flood protection).
6. Reconstruction costs were much larger than what was originally expected. A consortium consisting of five construction companies was assigned to the task of reconstructing the damaged houses. Mr The interviewee let us understand that it probably wasn't the cheapest way to rebuild the houses.

After the 2001 flood, the government compensated all property owners, even the households who had private flood insurance. When flooding happened earlier (1999, 2000) the governmental compensation-procedure looked different, the insurance compensation was then deducted from what was compensated by the government. But this last flood was considered to be the responsibility of the government, as it was a primary levee that burst (earlier this was not the case). Furthermore, political considerations were made – if the governmental compensation was reduced this time, nobody would buy private flood insurance in the future.

The government offered following compensation alternatives after the last flood (Bereg basin):

6. The property owner receives a new house in the same location, built in a material better suited to stand future floods (concrete house, standing on a 1.5 meter high foundation – this flood was about 1 meter high).

   Applied for: Severely damaged houses (destroyed).

7. The house is renovated on the expense of the government.

   Applied for: Moderately damaged houses.

8. The property owners could choose to leave the basin and buy a house of similar standard in other municipalities (but only within the county), with less flood risk. The old damaged house was then taken down. The government paid for the new house, controls were made to assure that the new house was of similar standard etc.

   Applied for: Severely damaged houses (destroyed) and for moderately damaged houses.

9. The property owners were given cash economic compensation; the size of the compensation handed out was lower than renovation costs for the house (25 000 HUF/m2 for adobe house, 50 000 HUF/m2 for non-adobe house).

People who received new houses must not sell them for 15 years.

Impacts: Since 206 people bought other houses, demand and real estate prices went up. (But the market values of the new houses are still about the half of the reconstruction costs). People have to spend much more money for the utility fees in these large, new houses (e.g., gas central heating, closed septic tanks – technically better solutions but expensive)

The property owners with damaged houses made the following choices (when 98 % of the households had made their choices):

1. 766 house owners received a new house on the same location
2. 1719 house owners had their homes renovated
3. 206 house owners choose to move out
4. 183 house owners received cash economical compensation

Opinion about the insurance options: The French system is preferred, but without making the insurance mandatory (this would be infeasible anyway). The government should help to make insurance more attractive (for example, insurance fees could be deducted from tax). It would be desirable that more people have insurances.

Currently, insurance companies pay 1% of their profit (1.5 billion HUF in total) to the government; this money is used for fire protection purposes. Such system could be extended to natural catastrophes. Cat-fund would be a good idea, as it has existed before, but the current government dismantled it.

APPENDIX 3: PRESENTATION OF SIMULATIONS OF THREE FLOOD MANAGEMENT STRATEGIES: THE PALAD-CSECSEI BASIN

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Introduction

In the design of different possible flood management policy scenarios, a key interest has been to find the balance between social solidarity and private/community responsibility. In this document, the consequences of imposing three different flood insurance policy scenarios are investigated. The studied scenarios are not necessarily optimal in any respect, but are constructed for the purpose of illuminating significant effects of adopting different insurance policies. Therefore, a main focus in this investigation is on insurance schemes in combination with compensation from the government. In particular, the subsidiary level has been taken into account, i.e. the amount of money transferred from the low-risk areas to the high-risk areas and from richer property-owners to poorer.

The simulations of the policy scenarios are based on data generated by a geographically explicit model for the Palad-Csecsei basin. This basin is situated in the Szabolcs-Szatmár-Bereg County. There are 4621 inhabitants in the basin and 2580 private properties. The county consists of 11 municipalities, of which mainly two experience flood damages.

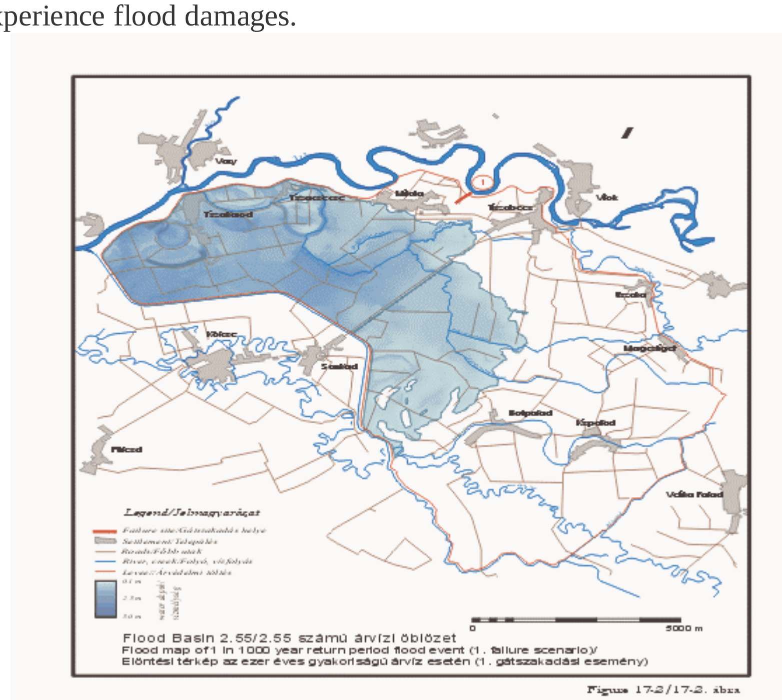


Figure 1. The Pilot basin experiencing a 1000-year flood. Failure at location 1.

Only floods resulting from levee failures are taken into account in the simulations. A levee failure occurs if a levee is overtopped or if it breaks and the water inundates neighbouring land. Groundwater related floods are excluded.

In the simulation model, levee failures may occur in one of three different locations. The levee failures result from floods of three magnitudes (100-year, 150-year, and 1000-year). There may be at most one levee failure per year. Each policy scenario is simulated for a 10-year period (a decade). The simulation of each policy scenario is iterated 10 000 times (100 000 years).

The probability distribution for the nine levee failure scenarios is presented in the appendix. Based on this distribution, the 'failure history' of 10 000 decades was produced. In most years, and also in most decades, no levee failures occurred. The same 'failure history' is used for the simulations of the three different policy scenarios. For each of the nine failure scenarios, a damage-function decides the economical damage for each property. The distribution of households with insurance is also fixed. Before the start of all simulations it was randomly determined for each property whether it was insured or not, based on the frequency of insured households in the region. This insurance choice for each property (insurance/no insurance) was fixed during all years, decades and simulations.

The output data of the simulations are:

- **Governmental load**:

  Compensation from government (plus subsidies in Scenario 3)

- **Balance for the insurance companies**:

  Premiums to flood insurance (2 per cent of total premiums if bundled) – Compensation from insurance companies

- **Balance for individual property-owners**:

  Compensation from government + Compensation from insurance companies – Property damages – Premiums to flood insurance (2 per cent of total premiums if bundled)

- **Balance per municipality (not presented explicitly)**:

  Compensation from government + Compensation from insurance companies – Property damages – Premiums to flood insurance (2 per cent of total premiums if bundled). This balance is an aggregate of all individual property-owners' balances in the municipality.

- **Balance for the entire Palad-Csecsei basin**:

  Compensation from government + Compensation from insurance companies – Property damages – Premiums to flood insurance (2 per cent of total premiums if bundled). This balance is an aggregate of all municipalities' balances.

The simulation rounds, consisting of 10 000 iterations of 10-year periods, produced 29 unique outcomes for the balance of the government, the municipalities, and the pilot basin. There were 22 unique outcomes for the insurers and 6 for the individual property-owner. The outcome is in this simulation the economic balance of a stakeholder, cumulated during a 10-year period.

To give a clearer overview of the results, the unique outcomes are clustered into five groups, and a weighted average for each group is presented in a table. The weighted average of each group (and each stakeholder) is calculated accordingly:

1. Each outcome in the group is multiplied by its frequency (number of decades it occurred).

2. The different products are summed together.

3. The sum is divided by the total number of occurrences in the group.

The output data are also presented in histograms that are clustered in five groups for readability. The groups are the same that are used in the tables. '–100' under a column means that the column represents the group with outcomes less than or equal to –100. The label always tells the upper limit of the group, the lower limit should be clear from the context. The height of the column tells the frequency (0 – 10 000) of the outcomes.

The first group in the tables (and the highest column in the histograms) contains only one outcome, from the decades without failures.

Policy Scenario 1: "Business As Usual"

This scenario is a continuation of the current system, where the central government is the main bearer of the economical responsibility.

The assumptions and settings are the following:

- The government compensates 60 per cent of property damages.
- 30 per cent of the households have private property insurance, a bundled insurance in which 2 per cent of the total premium accounts for flood insurance.
- Holders of private (bundled) insurance are compensated by 80 per cent by the insurance company.
- The insurance premium is not risk-based. It is based on the property-value (2 per cent of the property-value per year).

Results from simulations of scenario 1

Governmental load

Probability	Weighted Average Outcome
0,8818 (no failure)	0
0,0431	-9 372 425
0,0266	-122 222 481
0,0345	-227 255 130
0,0140	-794 509 286

Table 1. Governmental load, scenario 1.

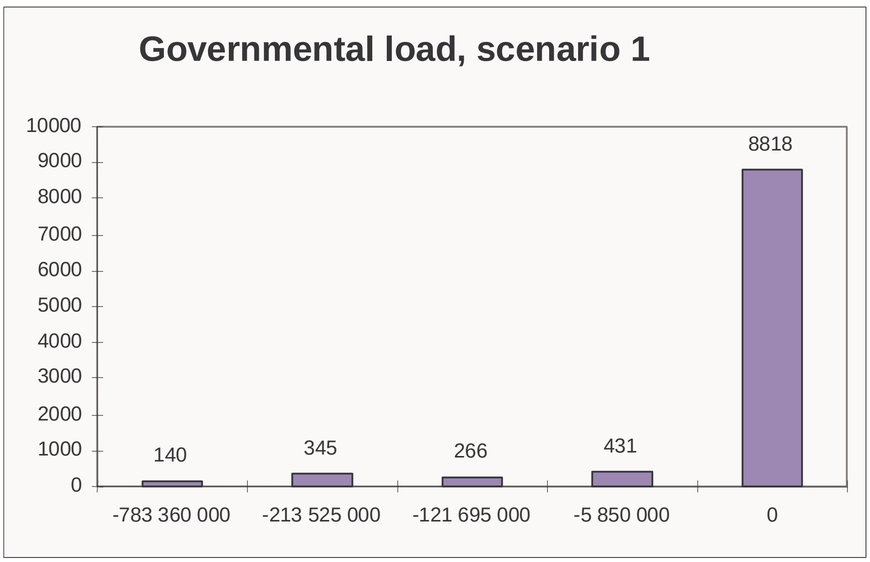


Figure 2. Histogram: Governmental load, scenario 1

The table and histogram in table 1 and figure 2 show that the costs for the government equal zero in most 10-year periods (in 88 per cent of the periods). In these decades no flood failures occur. In 431 decades the governmental load was in the range 5.8 million HUF to 121.7 million HUF. In the most extreme decade the load was slightly more than 1 billion HUF.

Balance for Pilot Basin

The balance for the Pilot basin is aggregated for all 11 municipalities in the following figures.

Probability	Weighted Average Outcome
0,8818 (no failure)	-2 276 800
0,0431	-17 932 566
0,0266	-230 715 672
0,0345	-434 214 423
0,0140	-1 540 519 800

Table 2. Pilot balance, scenario 1.

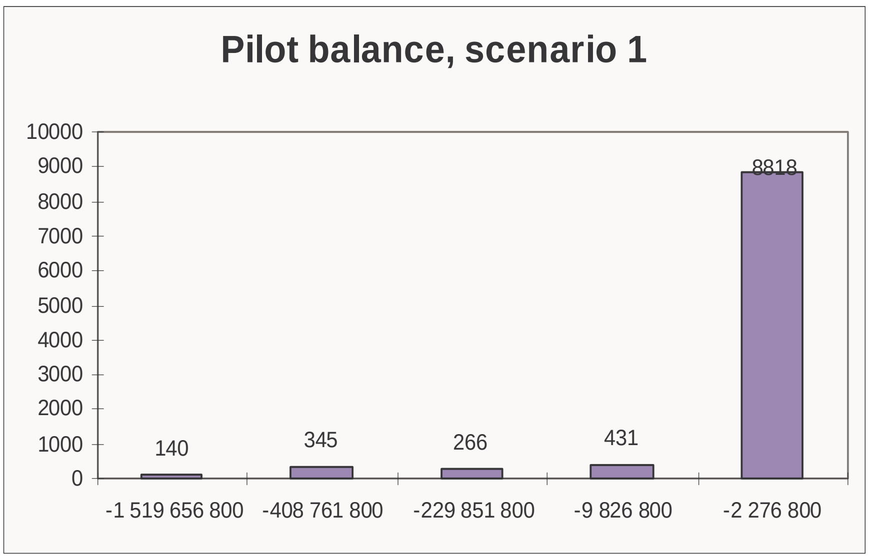


Figure 3. Histogram: Balance in entire Pilot basin.

The table and the histogram show that the result was negative in most decades; in 88 per cent the deficit amounted to 2 276 800 HUF. This is due to premium payments without retrieval of compensation. In 431 time-periods the result was more negative, in the range –9.8 million HUF to –229.8 million HUF to, see figure 3. In the most extreme decade the pilot basin made a negative result of 1.9 billion HUF.

Balance for Insurance Companies

When the balance for the insurance companies was investigated, only premium incomes from the Pilot basin was considered. Note that only 30 per cent of the property-owners in this region carry property insurance, as compared to 60 per cent in Hungary in total.

Probability	Weighted Average Outcome
0,8818 (no failure)	2 276 800
0,0431	-3 936 425
0,0266	-54 470 117
0,0345	-96 047 548
0,0140	-313 335 200

Table 3. Insurers balance, scenario 1.

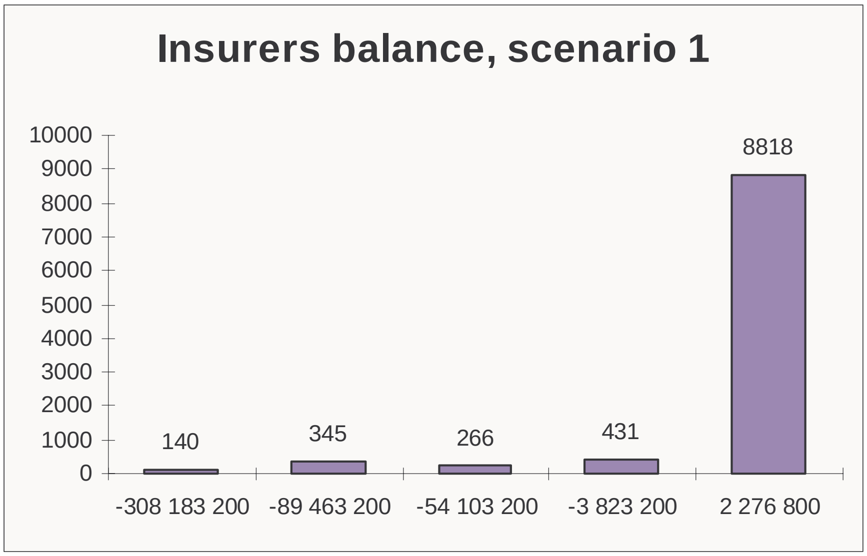


Figure 4. Histogram: Insurance companies balance, scenario 1.

The simulations show that the insurance companies make a profit in most decades, since they receive flood premiums (2 per cent of the bundled property insurance premium) while no compensations are paid, see figure 4. In decades with limited flood failures the balance is slightly negative, premiums are not sufficient to balance the compensations. In extreme decades the shortage is larger, in 140 time-periods the deficit was greater than -308 million HUF. In the most flood-hit decade the deficit amounted to -415 million HUF. An explanation to why the insurance companies show a negative result in many decades is the low fraction of insured households.

Balance for Individual Property-owner

The results for the individuals vary considerably, primarily depending on the location of the property. Only results for an example individual, with insurance and living in a high-risk location, is presented here.

Probability	Weighted Average Outcome
0,88180 (no failure)	-3 000
0,09130	1 347 000
0,02010	1 947 000
0,00520	2 697 000
0,00150	3 297 000
0,00010	4 647 000

Table 4. Individual balance, scenario1.

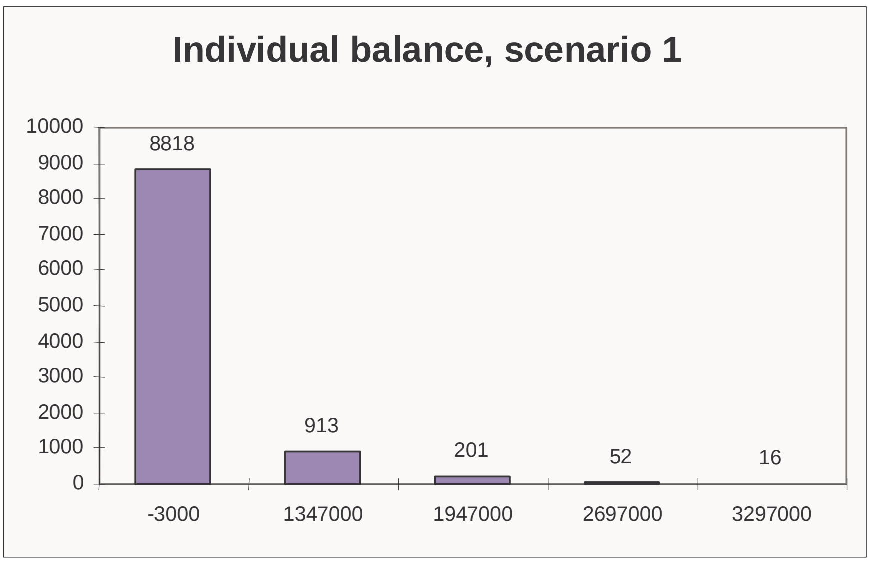


Figure 5. Histogram: individual property-owner, scenario 1.

In most decades the property-owner pays flood-premiums (300 HUF/year) without retrieving any compensation, since no levee failure occurs. When a failure occurs, the property-owner is compensated by the government (to 60 per cent of damages) and also by the insurance company, to 80 per cent of the damages. Because of this double-compensation, the property-owner gains economically if there is a levee failure. Since the premiums are based on the property value alone, the geographical risk is not reflected in the size of the premium, property-owners with insurance in low-risk locations subsidy the premiums for property-owners in high-risk locations. In 16 decades the property-owner profited largely, more than 3 million HUF.

Summary scenario 1

1. The governmental load is extensive in this scenario; compensations to individual property-owners are high, in extreme occasions more than 1 billion HUF.
2. Insurance companies in the pilot basin become insolvent (unless they have a large risk reserve) when there is a flood failure. As only 30 per cent of the property-owners are insured, the premium income is not sufficient.
3. Property-owners with insurance perform very well. They are doubly compensated; i.e. they are compensated by the government as well as by the insurance companies. The premiums are not risk-based, why a person in a high-risk area pays a subsidised premium. Individuals in high-risk areas can gain economically from flood failures.
4. The pilot basin balance is negative in most decades, since costs for premiums are paid. Largest positive outcome was more than 500 million HUF; many households in the basin were doubly compensated from flood failures.

Policy Scenario 2 "More Private Insurance"

In this scenario a part of the economic responsibility is shifted from the government to the property-owners. This is done by lowering the compensation from the government, as well as lowering the compensation from the subsidised property insurance; insurance 1. An additional insurance, insurance 2 is introduced, with a risk-based premium.

The assumptions and settings are the following:

- The government compensates (only) 30 per cent of property damages.
- 30 per cent of the households have a bundled insurance, in which 2 per cent of the total premium accounts for flood insurance. This is referred to as insurance 1.
- Holders of insurance 1 are compensated by 40 per cent of the damages by the insurance company
- The premium of insurance 1 is based on the property-value, 1 per cent of the property-value per year.
- Holders of risk-based insurance 2 are compensated by 100 per cent.
- 5 per cent of the households have a risk-based insurance (insurance2).
- The premium of insurance 2 is risk-based. It is based on the expected damage per municipality divided by the number of properties in the municipality.

Results from the simulations of policy scenario 2

Governmental load

Probability	Weighted Average Outcome
0,8818 (no failure)	0
0,0431	-4 686 212
0,0266	-61 111 241
0,0345	-113 627 565
0,0140	-397 254 643

Table 5. Governmental load, scenario 2.

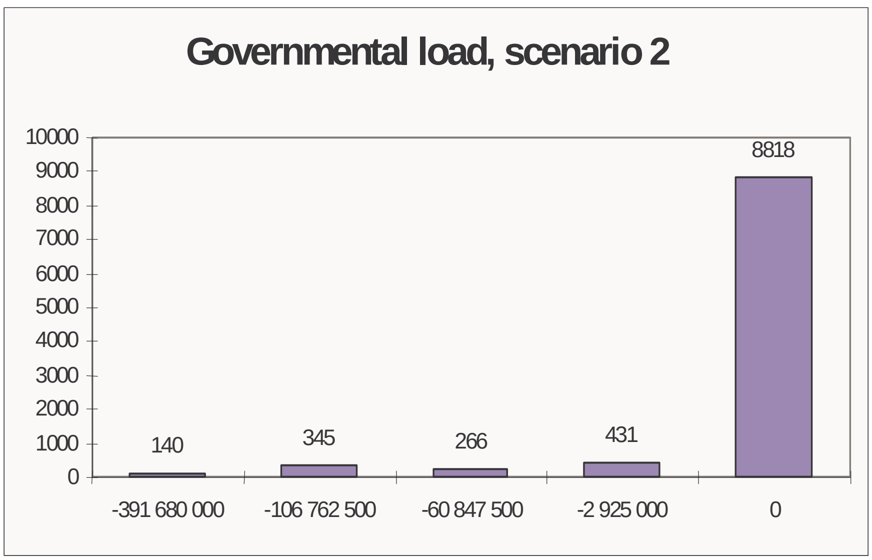


Figure 6. Histogram: Governmental load, scenario 2.

Most decades result in no flood failures and no compensation is paid to the households. In 431 time-periods the compensation paid to households were in the range 2.9 million HUF to 60.8 million HUF. In 751 decades large compensation were paid, the largest load for a 10-year period was 514.4 million, note that this load was much less than in scenario 1.

Balance for Pilot Basin

The balance for the entire basin (for 11 municipalities) shows, to some extent, how the area manages to recover when floods occur. A negative balance means that the region needs external aid.

Probability	Weighted Average Outcome
0,8818 (no failure)	-2 469 598
0,0431	-22 480 543
0,0266	-314 940 162
0,0345	-586 785 004
0,0140	-2 039 027 705

Table 6. Pilot Balance, scenario 2.

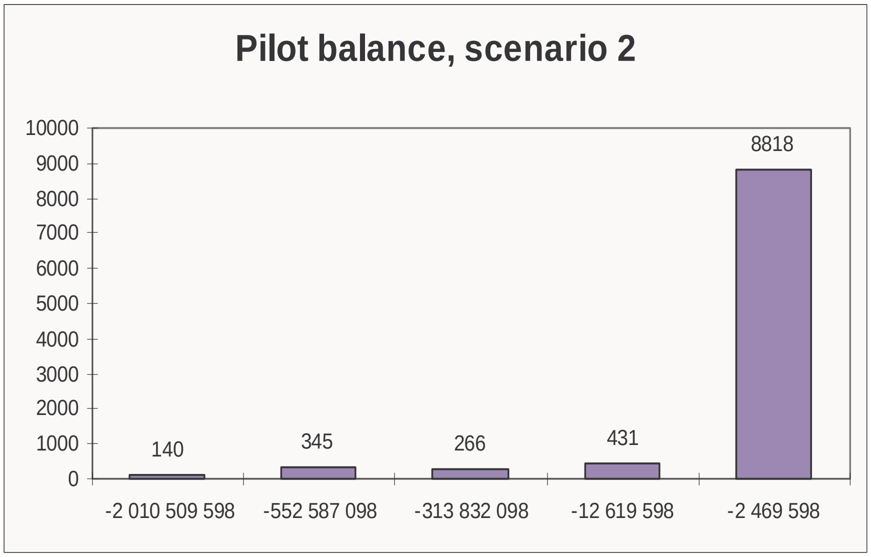


Figure 7. Histogram: Pilot basin balance, scenario 2.

In all simulated decades the pilot basin shows a negative balance, in failure-free decades the losses are 2.5 million HUF, consisting of the insurance premiums. The negative balance for the pilot basin can be explained by the low compensation from the government and the relatively low compensation from the subsidised insurance, in combination with the low fraction of households with the additional, risk-based, insurance. Extreme losses occur in 140 decades; in the worst-case decade loss amounted to 2.6 billion HUF.

Balance for Insurance Companies

The insurance companies receive premiums from two different insurances; one with subsidised premiums (30 per cent uptake rate in the Pilot basin) and one with risk-based premiums (5 per cent uptake rate).

Probability	Weighted Average Outcome
0,8818 (no failure)	2 276 800
0,0431	-4 074 660
0,0266	-31 356 868
0,0345	-57 104 532
0,0140	-212 081 938

Table 7. Insurers balance, scenario 2.

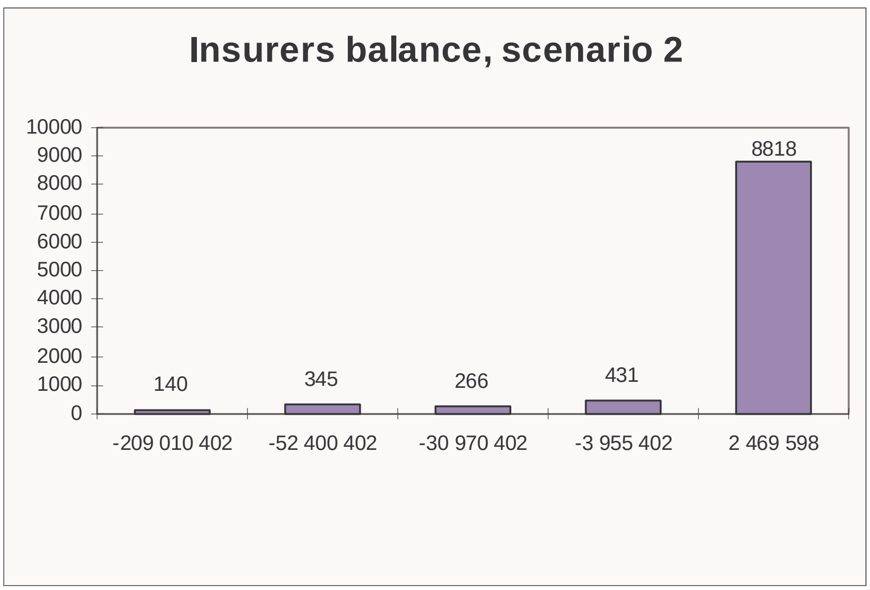


Figure 8. Histogram: balance for insurance companies.

Figure 8 shows the balance for the insurance companies. The balance is calculated by taking incomes in form of premiums, both subsidised and risk-based minus expenditures in form of compensation to insured households. The result shows that the balance is positive in most time-periods; a positive balance of approximately 2 million HUF. During decades with large flood disasters, the insurance companies pay less compensation than they did in scenario 1. The reason for this is the low compensation level for the subsidised insurance (1) in combination with the low uptake rate of risk-based insurance (2). The largest negative balance was 272.2 million HUF.

Balance for Individual Property-owner

A property-owner, who has both subsidised insurance 1 and risk-based insurance 2, pays large premiums if the property is located in a high-risk area. Premium amounts to slightly more than 80 thousands HUF per decade for this individual (668 HUF/ month), see table 8. When a flood failure occurs the individual is compensated quite richly, from two insurances as well as from the government.

Probability	Weighted Average Outcome
0,8818 (no failure)	-80 184
0,0913	2 282 316
0,0201	3 332 316
0,0052	4 644 816
0,0015	5 694 816
0,0001	8 057 316

Table 8. Individual property-owner, scenario 2.

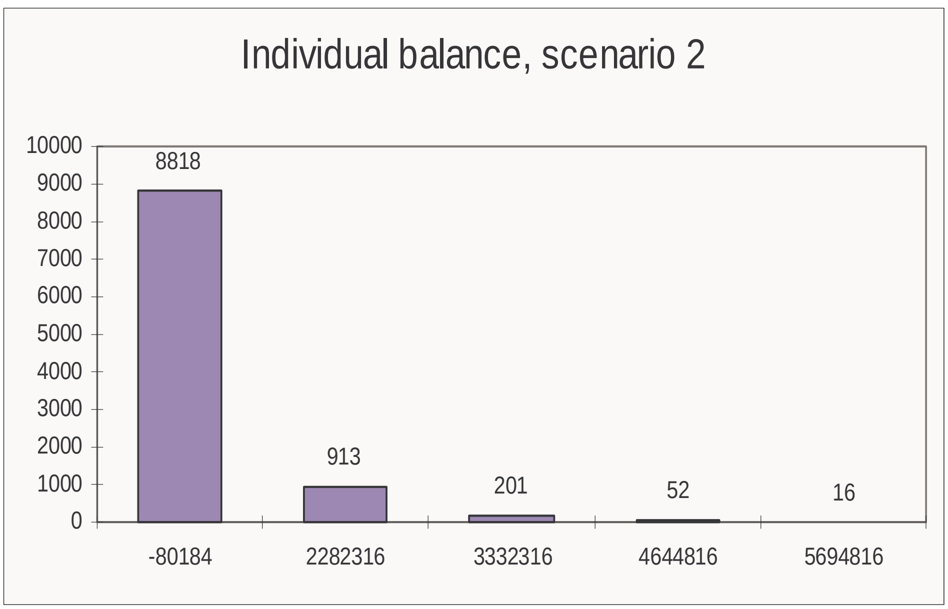


Figure 9. Histogram: balance for individual property-owner.

Summary scenario 2

5. The governmental load is substantially smaller than in scenario 1. The largest loss was 514.4 million HUF. The reason for this is that the compensation level was considerably lower than in scenario 1.

6. The Pilot basin balance shows a more negative result, since risk-based premiums are expensive for the property-owners and the compensation level is low for the subsidised insurance and from the government. In the worst-case scenario losses sum to 2.6 billion HUF.

7. Insurance companies are showing a more balanced result than in scenario 1. The incomes are a bit lower and the expenditures are smaller. The major shortage was 272 200 402 HUF.

8. Most property-owners are worse off than in scenario 1, since only five per cent are assumed to have risk-based insurance. Risk-based premiums are very expensive in municipalities 1 and 2. The example individual (figure 9) pays more than 8 thousand HUF per year in premiums for insurance 1 and 2. However, when flooding causes damage to a highly insured household, the property-owner collects high compensation; the risk-based insurance (2) compensates 100 per cent, plus the compensation from insurance 1, plus the compensation from the government.

Policy Scenario 3: "Catastrophe Fund"

In this scenario, a new institution is introduced, the all-hazard catastrophe fund. The fund combines the roles of the government and the insurance companies from scenarios 1 and 2. It is mandatory for all property-owners to contribute to the governmentally run catastrophe fund. Flood victims are compensated with 60 per cent of the losses from the catastrophe fund. The relatively low compensation is intended to stimulate property-owners to take own mitigation precautions. All property-owners must pay a mandatory fee of 1.5 per cent of their property value to the catastrophe fund per year.

The assumptions and the settings are the following:

- Compensation level is set to 60 per cent.
- Low-income households are subsidised, the government pays their contribution (fee) to the catastrophe fund.
- 60 per cent of the property-owners in the pilot basin are considered to be low-income households.

Results from simulations of scenario 3:

Balance for Catastrophe Fund

The balance for the re-insurance fund is calculated following:

fees from property-owners minus compensation to flood victims.

Probability	Weighted Average Outcome
0,8818 (no failure)	2 214 540
0,0431	-7 157 885
0,0266	-120 007 941
0,0345	-225 040 590
0,014	-792 294 746

Table 9. Catastrophe Fund balance, scenario 3.

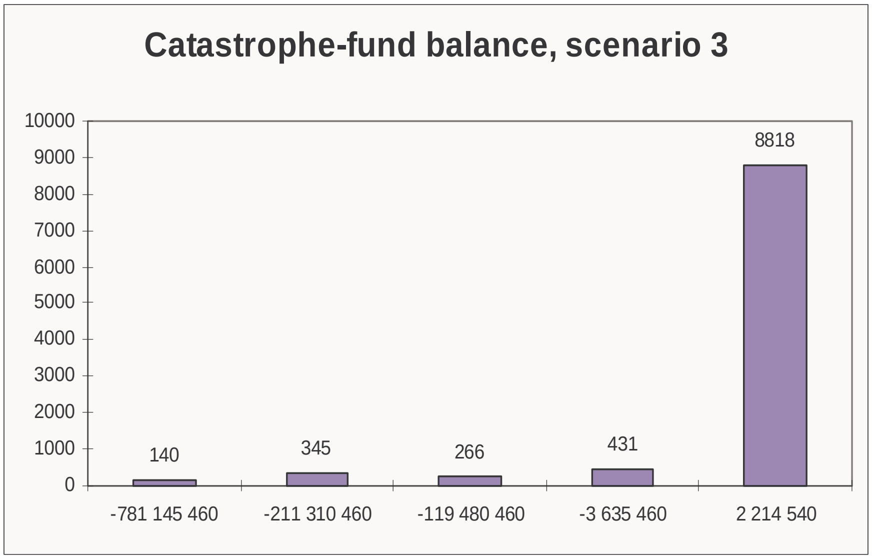


Figure 10. Balance for Catastrophe Fund

Figure 10 shows that the balance for the all-hazard catastrophe fund is positive in most 10-year periods. The surplus reaches more than 2 million HUF in failure-free decades. However, in 1182 ten-year periods, the catastrophe fund shows a negative balance. In 431 decades the deficit is larger than 300 million HUF, and in 140 decades the losses amount to 700 million HUF. The worst-case scenario shows a deficit of 1 billion HUF.

Governmental load

The load for the government is not treated separately in this scenario, as the catastrophe fund is a governmental institution. The load of the government would equal the negative balances of the catastrophe fund plus the subsidy to the low-income households.

Balance for entire Pilot basin

The balance for the entire Pilot basin (including all municipalities) is the difference between compensations and premiums.

Probability	Weighted Average Outcome
0,8818 (no failure)	-2 214 540
0,0431	-24 083 531
0,0266	-287 400 329
0,0345	-532 476 511
0,014	-1 856 069 540

Table 10. Pilot balance, scenario 3.

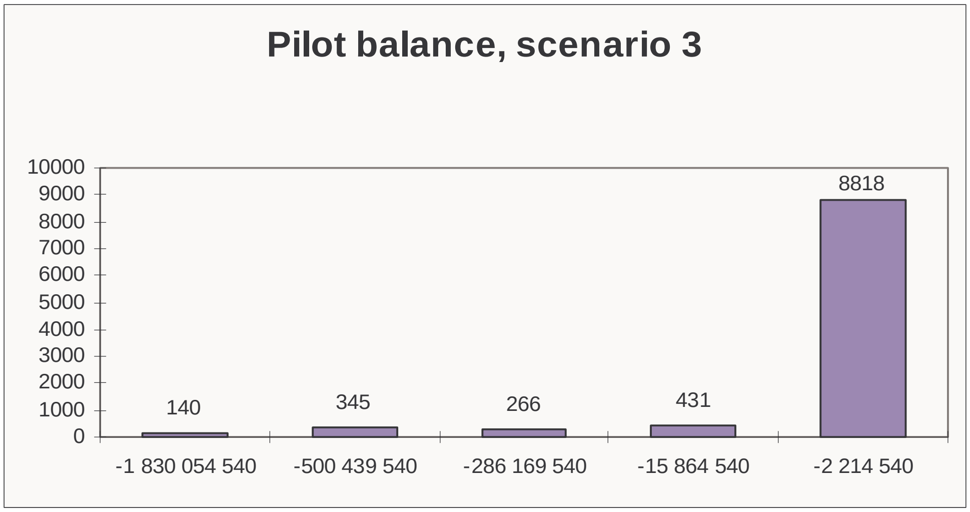


Figure 11. Balance for the Pilot basin, scenario 3.

The balance for the pilot region shows a negative result in all decades, see figure 11.

In most decades the balance is -2.2 million HUF. This corresponds to the fee paid to the catastrophe fund by the high-income households (40 per cent of the households). When failures occur, the balance is below 15.8 million HUF; the compensation is lower than the losses. The worst case scenario shows a deficit of as much as 2.4 billion HUF.

Balance for Individual property-owner (not a low-income household)

The balance for the individual property-owner consists of compensation from the insurance company minus fee to the all-hazard catastrophe fund minus property damages.

Probability	Weighted Average Outcome
0,8818 (no failure)	-2 250
0,0913	-1 352 250
0,0201	-1 952 250
0,0052	-2 702 250
0,0015	-3 302 250
0,0001	-4 652 250

Table 11. Individual property-owner, scenario 3.

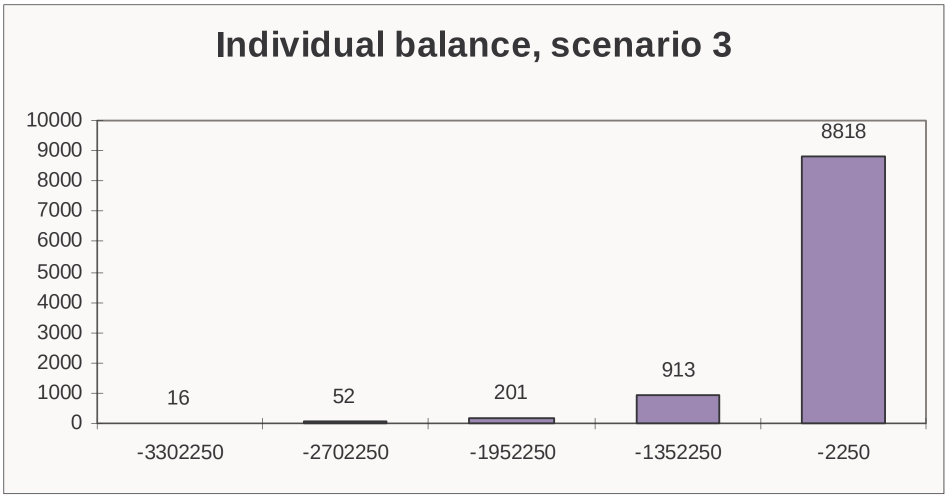


Figure 12. Individual property-owner, scenario 3.

Figure 12 shows that the balance never becomes positive, as the compensation level is lower than the damages (60 per cent). The fee to the catastrophe fund is 225 HUF per year for this example household, which is not a low-income household. For a low-income household, the government would however subsidise the entire fee.

Summary scenario 3

1. The governmental load is not presented explicitly in the 3rd scenario, however the government pays the fee for 60 per cent of the households in the region. Furthermore, the government would have to bail out the catastrophe fund when failures occur and the capital of the fund is insufficient.
2. The balance for the catastrophe fund is positive when no failures occur. The risk reserve of the fund is not enough to compensate losses when failures occur, why the government would have to help out.
3. The balance for the entire Pilot basin is negative in all decades. Compensation is lower than losses. The worst case scenario is a deficit of 2.4 billion HUF:
4. The individual property-owners show a negative balance, in high-risk locations as well as in low-risk locations. Even a poor household that collects governmental support for the fee to the catastrophe fund shows a negative balance when a failure occurs, as the compensation is low. No possibilities for the individuals to buy additional insurance are included in this scenario.

Appendices

The Simulation Model

The Upper Tisza Basin Flood Simulation Model consists of five modules, between which data is passed. See Figure 13. For each simulated year, the estimated economical consequences of flood failures are compiled and saved in the Consequence Module.

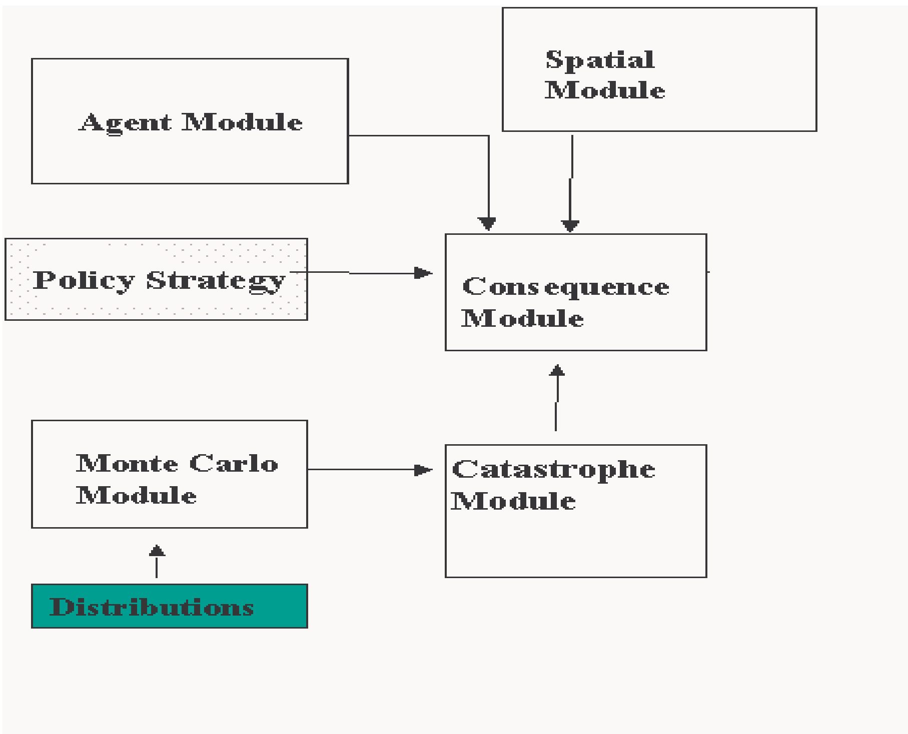


Figure 13. The five different modules in the Simulation Model

Monte Carlo Module

It is impossible to predict with certainty when and where flood will occur, random variables are used in the model to representing this uncertainty. These random variables represent whether there will be a levee failure or not, and where it will happen in that case. For each year, the variables are assigned random values from Monte Carlo module. The random outcome is passed to the Catastrophe module.

Catastrophe Module

At first, the value of the random variable *flood* is checked. In the simulation, only levee-failures are considered. A failure occurs when a levee is either overtopped or it breaks.

Nine different scenarios are considered. More precisely, three locations where the failure occurs are analysed. For each of these, floods of three different magnitudes: 100-year floods, 150-year floods, and 1000-year floods are assumed to cause the failures. The probabilities of the nine scenarios are presented in figure 14, below.

Scenarios	**Prob Failure (overtopping or breakage)**	**Prob Flood**	**Yearly Prob**
100 year, location 1:	0,12	0,01	0,0012
100 year, location 2:	0,20	0,01	0,002
100 year, location3:	0,28	0,01	0,0028
150 year, location1:	0,18	0,00667	0,0012
150 year, location2:	0,22	0,00667	0,0015
150 year, location3:	0,40	0,00667	0,0026
1000 year, location1:	0,19	0,001	0,00019
1000 year, location2:	0,33	0,001	0,00033
1000 year, location3:	0,45	0,001	0,00045

Figure 14. Probability-distribution for failure events (9 scenarios).

The Catastrophe module calculates how the water overflows the levees in case of a failure; what land areas are inundated, and by how deep water (the probability distribution and the inundation functions are delivered by Vituki Consulting, Hungary).

Spatial Module

The basin is geographically represented in form of a grid, in which each cell represent an area of 10 m^2. There are 1551* 1551 cells in the grid. For each cell, there is a rich amount of data for, e.g., soil type, land-use patterns digital elevations and property value. In the simulations, only structural losses are considered. Only 2508 of the cells contain property.

Consequence Module

This module is consulted when there has been a levee failure. For each inundated cell, the economic consequences are calculated. The Consequence module collects data on property values and vulnerability from the Spatial Module. The structural losses are estimated by a loss-function that is depending on initial property value and vulnerability.

Agent Module

The various stakeholders represented in the model are: the property-owner, the insurance companies, and the government. In the end of each simulated year, the economical situation for all agents is updated. If there has been a levee failure during the year, the property-value is reduced for all flooded cells. Premiums are paid annually. The economic consequences are a result of current policy strategy, i.e., the size of the premiums and compensations

Facts & Assumptions

Geographical data

County / Region

Size of region (Upper Tisza region):	approx. 5 400 km^2
County:	Szabolcs-Szatmár-Bereg
Neighboring countries:	Slovakia, the Ukraine and Romania
Land at risk for flood:	38 per cent (2 052 km^2)
No of settlements:	118
No of towns:	4
No of inhabitants:	200 000
Density:	
Unemployment rate:	24 per cent
Employment (branches):	
Agriculture:	35 per cent
Industry:	25 per cent
Service:	40 per cent
Main crops:	
	Corn
	Wheat
	Sunflower
	Fruits

Pilot basin 2.55

No of properties:	2 508
No of inhabitants:	4 621

Municipality	Inhabitants	Properties
Tiszakorod	780	407
Tiszacsecse	263	203
Milota	939	460
Sonkad	4	6
Tiszbecs	1 048	429
Uszka	295	153
Botpalad	581	413
Magosliget	240	169
Tiszaberek	0	0
Kishodos	0	0
Kispalad	471	340

River & flooding

Highest water run off from 1 km^2 (100-year flood):	2500 l/sec
Water run-off in low land areas (100-year flood)	500 l/sec
Increase of peak water levels past 95 years:	[0.35—0.73 cm/year]
Strength of major flood waves:	100 times larger than low (summer) level discharges
Max water flow:	4000 m3/sec
Max increase of water level:	11—12 meters

Mitigation

Levees:	627 km primary levee and a 94 km secondary levee
Standard of levees:	260 km of levee below standard (too low levee)
No of reservoirs (in the catchment area):	9
Total capacity of reservoirs:	576 million m3
Location of existing reservoirs:	mainly Romania, in the future possibly in Ukraine
History of major floods:	1970 (levee breaches), 1993, 1995, 1998, 1999, 2000, and 2001 (dike burst)

Consequences of 2001 flood:

No of inundated settlements	11
No of evacuated people	17 000
No of collapsed houses	200
No of damaged houses	5 600
Estimated total losses	23 billion HUF (76 million USD)

Levee failure probabilities

scen 1	= [0,12 * 1/100]	= 0.0012
scen 2		= 0.0020
scen 3		= 0.0028
scen 4		= 0.0012
scen 5		= 0.0015
scen 6		= 0.0027
scen 7		= 0.00018
scen 8		= 0.00033
scen 9		= 0.00045

Current Compensation Policies (government and insurance companies)

No statuary duty for the Government to compensate, but this is the practise anyway at least when a failure of a major levee occurs as this is considered the responsibility of the government. Insurance companies may limit pay-outs, for instance (Green): either for one property (5 million HUF) or total pay-outs (200 million , 400 million HUF).

Mitchell:

No of property insurers in Hungary	14
AB Aegon (the Netherlands)	56.4 % of market
Hungaria (German)	22.6 % of market
OTP-Granacia	17.9 % of market

Scenario Settings

Settings are summarized per scenario

Policy Scenario 1: "Business As Usual"

This scenario is a continuation of the current system, where government is the main bearer of the economical responsibility. The assumptions are the following:

Insurance Companies

Insurance type: Bundled with voluntary property/fire policies.

- Compensation (per cent of losses): 80 per cent
- Premium size (per cent of property value): 2 per cent
- Part of the total premium that constitutes flood insurance: 2 per cent
- Insurance rate (in the basin 5.1) 30 per cent

Government

- Compensation 60 per cent

Policy Scenario 2 "More Private Insurance"

In this scenario part of the responsibility is shifted from the government to the individual. This is done by lowering the compensation from the government as well as the compensation from the subsidised property insurance. A second, risk-based insurance is introduced.

Insurance Companies

- Compensation from insurance 1 (Subsidised insurance): 40 per cent
- Compensation from insurance 2 (Risk-based insurance): 100 per cent
- Premium size insurance 1, per cent of property value: 1 per cent
- Premium size insurance 2, risk based (expected losses for the municipality, divided by the number of properties in the municipality)
- Insurance rate, insurance 1: 30 per cent
- Insurance rate, insurance 2: 5 per cent

Government

Compensation 30 per cent

Scenario 3 (Catastrophe Fund)

A governmentally run catastrophe fund is introduced, it takes over the role of the insurance companies primarily.

- Take-up rate to the fund (mandatory) 100 per cent
- Fee size (based on property value): 1.5 per cent
- Compensation: 60 per cent
- Poverty rate (the proportion of property-owners in the pilot basin, that cannot afford premiums), the re-insurance fund will pay the insurance premium for those: 60 per cent

APPENDIX 4: DETAILED OUTPUT FROM THE SIMULATIONS

Scenario 1	Frequency	Outcome
Governmental Load		
	8818	0
	238	-5 850 000
	5	-11 700 000
	185	-13 635 000
	2	-19 485 000
	1	-27 270 000
	250	-121 695 000
	10	-127 545 000
	6	-135 330 000
	240	-213 525 000
	4	-219 375 000
	10	-227 160 000
	43	-239 685 000
	7	-243 390 000
	1	-245 535 000
	1	-251 385 000
	2	-253 320 000
	28	-278 370 000
	6	-335 220 000
	1	-361 380 000
	1	-400 065 000
	1	-427 050 000
	111	-783 360 000
	4	-789 210 000
	1	-796 995 000
	19	-815 355 000
	2	-905 055 000
	2	-996 885 000
	1	-1 028 880 000

Pilot Balance		
	8818	-2 276 800
	238	-9 826 800
	5	-17 376 800
	185	-27 991 800
	2	-35 541 800
	1	-53 706 800
	250	-229 851 800
	10	-237 401 800
	6	-255 566 800
	240	-408 761 800
	4	-416 311 800
	10	-434 476 800
	43	-456 821 800
	7	-457 426 800
	1	-464 371 800
	1	-471 921 800
	2	-482 536 800
	28	-531 006 800
	6	-636 336 800
	1	-684 396 800
	1	-758 581 800
	1	-815 246 800
	111	-1 519 656 800
	4	-1 527 206 800
	1	-1 545 371 800
	19	-1 579 171 800
	2	-1 747 231 800
	2	-1 926 141 800
	1	-1 985 656 800

Insurers Balance		
	8818	2 276 800
	423	-3 823 200
	8	-9 923 200
	250	-54 103 200
	16	-60 203 200
	240	-89 463 200
	14	-95 563 200
	43	-102 443 200
	3	-108 543 200
	7	-110 483 200
	1	-114 643 200
	28	-118 523 200
	6	-145 843 200
	1	-158 823 200
	1	-174 903 200
	1	-181 203 200
	111	-308 183 200
	5	-314 283 200
	19	-323 323 200
	2	-364 563 200
	2	-399 923 200
	1	-415 063 200

Scenario 2	Frequency	Outcome
Governmental Load		
	8818	0
	238	-2 925 000
	5	-5 850 000
	185	-6 817 500
	2	-9 742 500
	1	-13 635 000
	250	-60 847 500
	10	-63 772 500
	6	-67 665 000
	240	-106 762 500
	4	-109 687 500
	10	-113 580 000
	43	-119 842 500
	7	-121 695 000
	1	-122 767 500
	1	-125 692 500
	2	-126 660 000
	28	-139 185 000
	6	-167 610 000
	1	-180 690 000
	1	-200 032 500
	1	-213 525 000
	111	-391 680 000
	4	-394 605 000
	1	-398 497 500
	19	-407 677 500
	2	-452 527 500
	2	-498 442 500
	1	-514 440 000

Pilot Balance		
	8818	-2 469 598
	238	-12 619 598
	5	-22 769 598
	185	-34 677 098
	2	-44 827 098
	1	-66 884 598
	250	-313 832 098
	10	-323 982 098
	6	-346 039 598
	240	-552 587 098
	4	-562 737 098
	10	-584 794 598
	43	-617 217 098
	7	-625 194 598
	1	-627 367 098
	1	-637 517 098
	2	-649 424 598
	28	-714 284 598
	6	-863 949 598
	1	-928 579 598
	1	-1 025 647 098
	1	-1 102 704 598
	111	-2 010 509 598
	4	-2 020 659 598
	1	-2 042 717 098
	19	-2 092 842 098
	2	-2 321 872 098
	2	-2 560 627 098
	1	-2 642 959 598

Insurers Balance		
	8818	2 469 598
	423	-3 955 402
	8	-10 380 402
	250	-30 970 402
	16	-37 395 402
	240	-52 400 402
	14	-58 825 402
	43	-61 890 402
	7	-64 410 402
	3	-68 315 402
	28	-74 430 402
	1	-74 740 402
	6	-85 840 402
	1	-95 330 402
	1	-107 270 402
	1	-107 870 402
	111	-209 010 402
	5	-215 435 402
	19	-217 330 402
	2	-242 450 402
	2	-263 880 402
	1	-272 200 402

Scenario 3 Governmental Load	Frequency	Outcome
	8818	2 214 540
	238	-3 635 460
	5	-9 485 460
	185	-11 420 460
	2	-17 270 460
	1	-25 055 460
	250	-119 480 460
	10	-125 330 460
	6	-133 115 460
	240	-211 310 460
	4	-217 160 460
	10	-224 945 460
	43	-237 470 460
	7	-241 175 460
	1	-243 320 460
	1	-249 170 460
	2	-251 105 460
	28	-276 155 460
	6	-333 005 460
	1	-359 165 460
	1	-397 850 460
	1	-424 835 460
	111	-781 145 460
	4	-786 995 460
	1	-794 780 460
	19	-813 140 460
	2	-902 840 460
	2	-994 670 460
	1	-1 026 665 460

Pilot Balance		
	8818	-2 214 540
	238	-15 864 540
	5	-29 514 540
	185	-34 029 540
	2	-47 679 540
	1	-65 844 540
	250	-286 169 540
	10	-299 819 540
	6	-317 984 540
	240	-500 439 540
	4	-514 089 540
	10	-532 254 540
	43	-561 479 540
	7	-570 124 540
	1	-575 129 540
	1	-588 779 540
	2	-593 294 540
	28	-651 744 540
	6	-784 394 540
	1	-845 434 540
	1	-935 699 540
	1	-998 664 540
	111	-1 830 054 540
	4	-1 843 704 540
	1	-1 861 869 540
	19	-1 904 709 540
	2	-2 114 009 540
	2	-2 328 279 540
	1	-2 402 934 540

Insurers Balance		
	8818	2 469 598
	423	-3 955 402
	8	-10 380 402
	250	-30 970 402
	16	-37 395 402
	240	-52 400 402
	14	-58 825 402
	43	-61 890 402
	7	-64 410 402
	3	-68 315 402
	28	-74 430 402
	1	-74 740 402
	6	-85 840 402
	1	-95 330 402
	1	-107 270 402
	1	-107 870 402
	111	-209 010 402
	5	-215 435 402
	19	-217 330 402
	2	-242 450 402
	2	-263 880 402
	1	-272 200 402

APPENDIX 5: THE EXTENDED DELTA METHOD (EDM)

Mats Danielson & Love Ekenberg

ABSTRACT

The method used for evaluating the flood risk management policy decision problem in the Upper Tisza Basin (UTB) is based on the Delta method (Danielson 98). It has been further developed and extended to handle a problem model in which several stakeholders' outcomes can be handled on a per consequence basis. Thus, it is a multi-criteria extension to the basic probabilistic method. Previously, the Delta method was able to handle either probabilistic or criteria models, but not both. With symmetrical trees, as in the problem treated in this report, both can be handled. Further, the use of multi-level trees, which was previously only a theoretical possibility, has now been field tested.

In EDM, the decision-maker automatically makes his problem statements more visible and only with the precision he feels he has evidence for at that moment. This brings about a number of advantages. First, he must make the underlying information clear, and second, the statements can be the subject of discussions with (and criticism from) other participants in the decision process. Third, it can also be seen more clearly which information is required in order to take the problem closer to a decision and within which areas some more information must be gathered before a well-founded decision can be made. Fourth, arguments for (and against) a specific selection can be derived from the analysis material. Fifth, the decision can be better documented, and the underlying information as well as the reasoning leading up to a decision can be traced afterwards. The decision can even be changed in a controlled way, should new information become available at a later stage.

First, a general introduction to the method is given. Following that, the conceptual model is discussed, and finally, the evaluation procedure and its interpretations are treated.

Introduction

Suppose a decision-maker wants to evaluate a specific decision situation. In order to approach the problem in a reasonable way, given available resources, a decision process such as the following could be employed, not necessarily in the exact order given.

- Clarify the problem, divide it into sub-problems if necessary
- Decide which information is a prerequisite for the decision
- Collect and compile the information
- Define possible courses of action
- For each alternative:
    - Identify possible consequences
    - For each consequence:
        - Estimate how probable it is
        - Estimate the value of it occurring for each stakeholder

• Disregard obviously bad courses of action

• Based on the above, evaluate the remaining alternatives

• Carry out a sensitivity analysis

The method described in the following should be seen in the context of such a decision process.

The EDM process

The EDM process is carried out in a number of steps. The first step is a bit special, since there is much information to collect. The initial information is gathered from different sources. Then it is formulated in statements and entered into the computer tool. Following that, an iterative process commences where step by step the decision-makers gain further insights. During this process, the decision-makers receive help in realizing which information is missing, is too vague, or is too precise. They might also change the problem structure by adding or removing consequences or even entire alternatives, as more information becomes available.

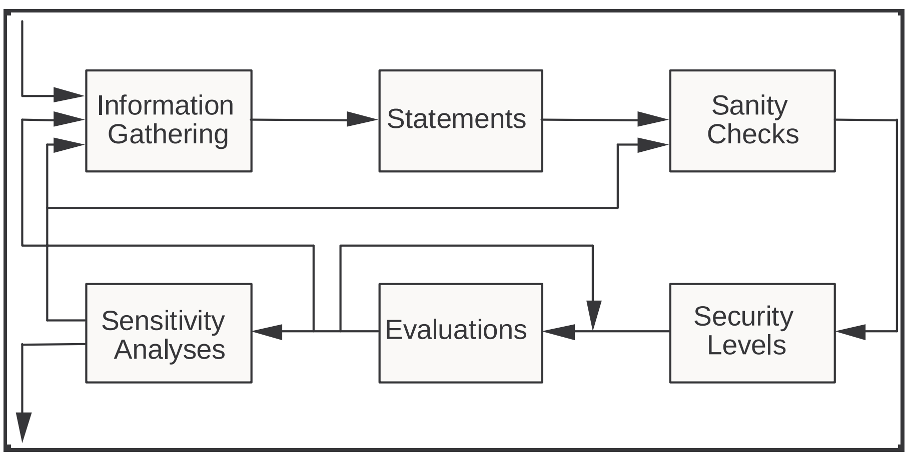


Figure 1 The EDM process

Information Gathering

In some cases, the first information collection phase can be a very long and tedious step. Sometimes, it might take man-months. In other cases, it might only require a few half-day discussions with experts. It is impossible to describe any typical case because the situations are too diverse. In the Upper Tisza Basin case, much work ranging from interviews to simulation was required.

Modeling

After the data collection phase, a modeling task commences where the decision-maker structures and orders the information. Given the set of stakeholders, he tries to compile a smaller number of reasonable courses of action and identify the consequences belonging to each alternative. In the UTB case, simulation results were clustered into meaningful sets. There is no requirement for the alternatives to have the same number of consequences. However, within any given alternative, it is required that the consequences are exclusive and exhaustive, i.e. whatever the result, it should be covered by the description of exactly one consequence. This is unproblematic, since a residual consequence can be added to take care of unspecified events.

The probability and value statements plus the weights are represented by interval constraints and core intervals described later. Intervals are a natural form in which to express such imprecise statements. It is not required that the consequence sets are determined from the outset. A new consequence may be added at a later stage, thus facilitating an incremental style of working.

Decision Frames

In EDM, a *decision frame* represents a decision problem. The idea with such a frame is to collect all information necessary for the model in one structure. This structure is then filled in with user statements. All the probability statements in a decision problem share a common structure because they are all made relative to the same decision frame. They are translated and collected together in a *probability base*. For value statements, the same is done in a *value base*. Finally, stakeholder weights are also supplied. The correspondence between the user model and the representation is summarized in Table 1.

User model	Representation
Decision problem	Decision frame
Alternative	Consequence set
Consequence, event	Consequence
Collection of statements	Base
Interval statement	Core interval
	Interval constraint

Table 1 Representation of user model

In practice, a model of the situation is created with stakeholders, relevant courses of action, and their consequences when specific events occur. The model is represented by a decision frame. The courses of action are called alternatives in the user model, and they are represented by consequence sets in the decision frame. If the problem contains more than one decision level, it is internally transformed into an alternative–consequence form (AC-form), a one-level decision tree that is a computationally equivalent representation. In the user interface, all levels are kept as they were originally entered. Following the establishment of a decision frame in the tool, the probabilities of the events and the values of the consequences are subsequently filled in. A part of the user multi-level tree for UTB is shown in figure 2. For the first scenario, the three most likely outcomes are shown with their probability and value ranges. The last level is the local weights as described later.

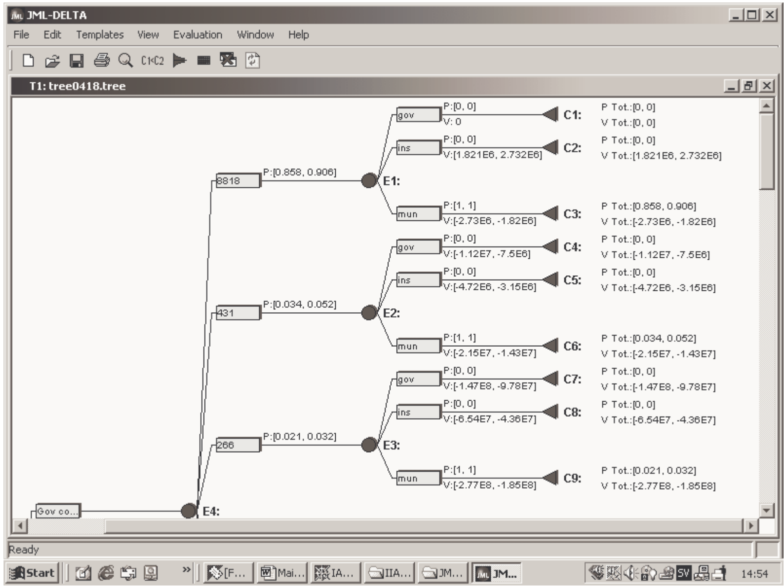


Figure 2: A multi-level tree for UTB

Frame Structure

A decision frame must capture the structure of the tree internally in the tool once transformed into one-level form. A one-level tree consists primarily of sets of consequences. Then, there are statements of probability and value collected in structures called constraint sets and cores.

> **Definition:** Given a set of variables $S = \{x_i\}$, a continuous function $g:S^n \to [0,1]$, and real numbers $a,b \in [0,1]$ with $a \le b$, an *interval constraint* $g(x_1,\ldots,x_n) \in [a,b]$ is a shorter form for a pair of weak inequalities $g(x_1,\ldots,x_n) \ge a$ and $g(x_1,\ldots,x_n) \le b$.

In this manner, both equalities and inequalities can be handled in a uniform way since equalities are represented by intervals [a,a]. A collection of interval constraints concerning the same set of variables is called a *constraint set*. It follows that a constraint set can be seen as a system of inequalities. For such a system to be meaningful, there must exist some vector of variable assignments that satisfies each inequality in the system simultaneously.

> **Definition:** Given a set of variables $\{x_i\}$, a constraint set X in $\{x_i\}$ is *consistent* **iff** the system of weak inequalities in X has a solution.[2] Otherwise, the constraint set is *inconsistent*. A constraint Z is *consistent with* a constraint set X **iff** the constraint set $\{Z\} \cup X$ is consistent.

In other words, a consistent constraint set is a set where the constraints are at least not contradictory.

[2]Then there is a non-empty solution set for X.

Definition: Given a consistent constraint set X in $\{x_i\}$ and a function f,
$X_{max}(f(x)) =_{def} \sup(a \mid \{f(x) > a\} \cup X \text{ is consistent})$. Similarly,
$X_{min}(f(x)) =_{def} \inf(a \mid \{f(x) < a\} \cup X \text{ is consistent})$

The orthogonal hull is a concept that in each dimension signals which parts are definitely incompatible with the constraint set. The orthogonal hull can be pictured as the result of wrapping the smallest orthogonal hyper-cube around the constraint set.

Definition: Given a consistent constraint set X in $\{x_i\}_{i\in I}$, the set of pairs $\{\langle X_{min}(x_i), X_{max}(x_i)\rangle\}$ is the *orthogonal hull* of the set and is denoted $\langle X_{min}(x_i), X_{max}(x_i)\rangle_n$.

Constraints and core intervals have different roles in specifying a decision situation. The constraints represent "negative" information, which vectors are not part of the solution sets. The contents of constraints specify which ranges are infeasible by excluding them from the solutions. This is in contrast to core intervals, which represent "positive" information in the sense that the decision maker enters information about sub-intervals that are felt to be the most central ones and that no further discrimination is possible within those ranges.

Definition: Given a constraint set X in $\{x_i\}$ and the orthogonal hull $\langle a_i,b_i\rangle_n$ of X, a *core interval* of x_i is an interval $[c_i,d_i]$ such that $a_i \le c_i \le d_i \le b_i$. A *core* $[c_i,d_i]_n$ of $\{x_i\}$ is a set of core intervals $\{[c_i,d_i]\}$, one for each x_i.

As for constraint sets, the core might not be meaningful in the sense that it may contain no possible variable assignments able to satisfy all the inequalities. This is quite similar to the concept of consistency for constraint sets, but for core intervals, the requirement is slightly different. It is required that the focal point is contained within the core.

Definition: Given a consistent constraint set X in $\{x_i\}$ and a focal point $\mathbf{r} = (r_1,\ldots,r_n)$, the core $[c_i,d_i]_n$ of $\{x_i\}$ is *permitted with respect to r* **iff** $c_i \le r_i \le d_i$.

Together, constraint sets and cores delimit the shape of the belief in the numerical values for the variables, see figure 3.

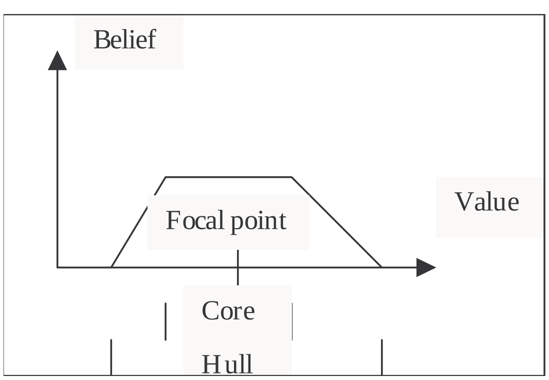


Figure 3: The hull, core and focal point for a variable

Bases

A base consists of a constraint set for a set of variables together with a core. A base is simply a collection of constraints and the core that belongs to the variables in the set. The idea with a base is to represent a class of functions over a finite, discrete set of consequences.

> **Definition:** Given a set $\{x_i\}$ of variables and a focal point **r**, a *base* X in $\{x_i\}$ consists of a constraint set X_C in $\{x_i\}$ and a core X_K of $\{x_i\}$. The base X is *consistent* if X_C is consistent and X_K is permitted with respect
> to **r**.

Probability Bases

The collection of probability statements in a decision situation is called the *probability base*. A probability base is said to be *consistent* if it can be assigned at least one real number to each variable so that all inequalities are simultaneously satisfied. The idea is that no meaningful operations can take place on a set of statements that have no variable assignments in common, since there is no way to take all the requirements into account. Note that the method deals with classes of functions of which there are infinitely many instantiations, and insists on at least one of them yielding consistent results.

> **Definition:** Given a set $\{C_{ik}\}$ of disjoint and exhaustive consequences, a base P in $\{p_{ik}\}$, and a discrete, finite probability mass function $\prod:C\rightarrow[0,1]$ over $\{C_{ik}\}$. Let p_{ik} denote the function value $\prod(C_{ik})$. $\prod$ obeys the standard probability axioms, and thus $p_{ik} \in [0,1]$ and $\sum_k p_{ik} = 1$ are default constraints in the constraint set P_C. Then P is a *probability base*.

Thus, a probability base can be seen as characterizing a set of discrete probability distributions. The core P_K can be thought of as an attempt to estimate a class of mass functions by estimating the individual discrete function values.

Value Bases

Requirements similar to those for probability variables can be found for value variables. There are apparent similarities between probability and value statements but there are differences as well. The normalization ($\sum_k p_{ik} = 1$) requires the probability variables of a set of exhaustive and mutually exclusive consequences to sum to one. No such dimension reducing constraint exists for the value variables.

> **Definition:** Given a set $\{C_{ik}\}$ of disjoint and exhaustive consequences, a base V in $\{v_{ik}\}$, and a discrete, finite value function $\Omega:C\rightarrow[0,1]$. Let v_{ik} denote the function value $\Omega(C_{ik})$. Because of the range of Ω, $v_{ik} \in [0,1]$ are default constraints in the constraint set V_C. Then V is a *value base*.

Similar to probability bases, a value base can be seen as characterizing a set of value functions. The value core V_K can be seen as an attempt to estimate a class of value functions.

The probability and value bases together with structural information constitute the *decision frame*.

Frames

Using the above concepts of consequence, constraint, core, and base, it is possible to model the decision-makers' situation in a decision frame. Compare the decision frame to Table 1 at the beginning of the appendix. The frame captures a decision problem on AC-form, a one-level tree problem in normal form. The frame is also the key data structure in the tool implementation, holding references to other structure information and to the bases containing most of the information. All statements entered via the tool user interface are collected in the decision frame. When all statements in the current state of the problem have been entered, the data entry phase is over for the time being. As the insights into the decision problem accumulate during all the following phases, it is possible to add new information and alter or delete information already entered.

Sanity Checks

Thereafter, the work continues with evaluating the alternatives. It begins by comparing the alternatives as they are entered. As the first evaluation step, the *sanity* of the decision frame is checked. Much information collected, especially in large investigations, run the risk of being cluttered or misunderstood during the process. If some data in the frame is problematic, the decision-maker could consider leaving it out of the current cycle or recollecting it. Missing data is easily handled for later inclusion. For example, a missing consequence can be added at a later stage. If the set of consequences for some alternative is not exhaustive, a residual consequence can be temporarily added. Missing value constraints can be temporarily substituted with very wide intervals or just left out. Such possibilities have certain advantages as the results emerging at the outset of the evaluation may be viewed with greater confidence than if erroneous data is entered.

Security Levels

Many decisions are one-off decisions, or are important enough not to allow a too undesirable outcome regardless of its having a very low probability. The common aggregate decision rules will not rule out an alternative with such a consequence provided it has a very low probability. If the probability for a very undesirable consequence is larger than some *security level*, it seems reasonable to require that the alternative should not be considered, regardless of whether expected value shows it to be a good course of action. If the security level is violated by one or more consequences in an alternative and this persists beyond a predetermined rate of cutting (described below), then the alternative is *unsafe* and should be disregarded. An example of security leveling is an insurance company desiring not to enter into insurance agreements where the profitability is high but there is a very small but not negligible risk for the outcome to be a loss large enough to put the company's existence at stake. The security analysis requires some parameters to be set. Security levels is an important supplement to the expected value, but have not been used in the UTB case, mainly due to the fact that the different scenarios handle reinsurance in different ways. A security level setting would prohibit instances where an insurance company could go bankrupt, but this is usually solved by reinsurance instead.

Evaluations

After having taken security levels into account, which value does a particular decision have? In cases where the outcomes can be assigned monetary values, it seems natural that the value of the decision should be some kind of aggregation of the values of the individual consequences. The ultimate comparing rule of an evaluation in EDM as well as in many other methods is the expected value (EV), sometimes instantiated as the expected utility or the expected monetary value. Since neither probabilities nor values are fixed numbers, the evaluation of the expected value yields quadratic (bilinear) objective functions of the form

$$EV(A_i) = p_{i1}v_{i1} + \ldots + p_{in}v_{in},$$

where the p_{ik}'s and v_{ik}'s are variables. Further complicating the picture is the presence of different stakeholders, which have their own specific values that must be weighted together. For s stakeholders, this leads to the expression

$$EV(A_i) = w_1 (p_{1i1}v_{1i1} + \ldots + p_{1in}v_{1in}) + \ldots + w_s (p_{si1}v_{si1} + \ldots + p_{sin}v_{sin}),$$

where w_k is the importance weight of stakeholder k.

Maximization of such expressions are computationally demanding problems to solve in the general case, using techniques from the area of non-linear programming. Fortunately, in the UTB case, the decision trees are symmetrical with respect to the stakeholders, i.e. the trees, the alternatives, the consequences, and thus the probabilities coincide. This leaves us with differing values and weights. By multiplying in the weights and making the probabilities common, the expression can be rewritten

$$EV(A_i) = p_{i1} w_1v_{1i1} + \ldots + p_{in} w_1v_{1in} + \ldots + p_{i1} w_s v_{si1} + \ldots + p_{in} w_s v_{sin},$$

which finally is written

$$EV(A_i) = p_{i1} (w_1v_{1i1} + \ldots + w_s v_{si1}) + \ldots + p_{in} (w_1v_{1in} + \ldots + w_s v_{sin}),$$

thus permitting local (at consequence level) culling of weighted values.

Maximization of such expressions are less but still computationally demanding problems to solve, using techniques from the area of quadratic programming. In (Danielson 98) there are discussions about and proofs of the existence of computational procedures to reduce the problem to systems with linear objective functions, solvable with ordinary linear programming methods.

When a rule for calculating the EV for decision frames containing interval statements is established, the next question is how to compare the courses of action using this rule. It is not a trivial task, since usually the possible EVs of several alternatives overlap. The most favourable assignments of numbers to variables for each alternative usually render that alternative the preferred one. The fiirst step towards a usable decision rule is to establish some concepts that tell when one alternative is preferable to another. For simplicity, only two alternatives are discussed even though UTB contains three, but the reasoning can easily be generalized to any number of alternatives.

Definition: The alternative A_1 is *at least as good as* A_2 if $EV(A_1) \geq EV(A_2)$ for all consistent assignments of the probability and value variables.

The alternative A_1 is *better than* A_2 if it is at least as good as A_2 and further $EV(A_1) > EV(A_2)$ for some consistent assignments of the probability and value variables.

The alternative A_1 is *admissible* if no other alternative is better.

If there is only one admissible alternative it is obviously the preferred choice. Usually there are more than one, since apparently good or bad alternatives are normally dealt with on a manual basis long before decision tools are brought into use. All non-admissible alternatives are removed from the considered set and do not take further part in the evaluation. The existence of more than one admissible alternative means that for different consistent assignments of numbers to the probability and value variables, different courses of action are preferable. When this occurs, how is it possible to find out which alternative is to prefer?

Let $\delta_{12} = EV(A_1) - EV(A_2)$ be the differences in expected value between the alternatives. The *strength* of A_1 compared to A_2, given as a number $\max(\delta_{12}) \in [-1,1]$, shows how the most favourable consistent assignments of numbers to the probability and value variables lead to the greatest difference in the expected value between A_1 and A_2. In the same manner, A_2 is compared to A_1. These two strengths need not sum to one or to any other constant – the first might for example be 0.2 and the second 0.4. If there are more than two alternatives, pair wise comparisons are carried out between all of them.

Furthermore, there is a strong element of comparison inherent in a decision procedure. For example, statements such as $v_{11} > v_{22}$ are not taken into account when calculating maximal and minimal $EV(A_i)$ unless they influence the hull. As the results are interesting only in comparison to other alternatives, it is reasonable to consider the differences in strength as well. Therefore, it makes sense to evaluate the *relative strength* of A_1 compared to A_2 in addition to the strengths themselves, since such strength values would be compared to some other strengths anyway in order to rank the alternatives. The relative strength between the two alternatives A_1 and A_2 are calculated using the formula

$$\text{mid}(\delta_{12}) = [\max(\delta_{12})+\min(\delta_{12})]/2 = [\max(\delta_{12}) - \max(\delta_{21})]/2$$

The concept of strength is actually somewhat more complicated. Dominance means that one consequence set is superior to another, at least in a part of the solution space to the bases. The weakest relation would be if "a part" refers to a single solution vector. A more reasonable interpretation of "a part" is if it is superior in a substantial fraction of the solutions. Dominance in the strongest sense would mean to require that the "part" consists of all solution vectors. This idea is captured in the concepts of strong, marked, and weak dominances. They correspond to the minimal, medium, and maximal differences. Alternative A_1 is said to strongly dominate alternative A_2 if $\min(\delta_{12}) > 0$, to markedly dominate if $\mathrm{mid}(\delta_{12}) > 0$, and finally to weakly dominate if $\max(\delta_{12}) > 0$. This is further explained in (Danielson 03).

Cutting the Hull

The hull cut is a generalized sensitivity analysis to be carried out in a large number of dimensions. In non-trivial decision situations, when a decision frame contains numerically imprecise information, the different principles suggested above are often too weak to yield a conclusive result by themselves. Only studying the differences in the expected value for the complete bases often gives too little information about the mutual strengths of the alternatives. Thus, after the elimination of undesirable consequence sets, the decision-maker could still find that no conclusive decision has been made. One way to proceed is to determine the stability of the relation between the consequence sets under consideration.

A natural way to investigate this is to consider values near the boundaries of the constraint intervals as being less reliable than the core due to the former being deliberately imprecise. Hence, it is important to be able to study the strengths (or dominances) between the alternatives on sub-parts of the bases. If a dominance is evaluated on a sequence of ever-smaller sub-bases, a good appreciation of the strength's dependency on boundary values can be obtained. This is taken into account by cutting off the dominated regions indirectly using the hull cut operation. This is denoted *cutting* the bases, and the amount of cutting is indicated as a percentage β, which can range from 0% to 100%. For a 100% cut, if no core is specified, the bases are transformed into single points, and the evaluation becomes the calculation of the ordinary expected value.

> **Definition:** Given a base X, a set of real numbers $\{a_i,b_i\}$, a hull $[c_i,d_i]_n$, and a real number $\beta \in [0,1]$, a *β-cut* of X is to replace the hull by $[c_i-(1-\beta)\cdot(a_i-c_i),\ d_i-(1-\beta)\cdot(b_i-d_i)]_n$.

It is possible to regard the hull cut as an automated kind of sensitivity analysis. In order to maintain consistency, the cut decreases the bases in predefined ways. Since the belief in peripheral values is somewhat less, the interpretation of the cut is to zoom in on more believable values that are more centrally located.

The principle can also be motivated by the difficulties of performing simultaneous sensitivity analysis in several dimensions at the same time. It can be hard to gain real understanding of the solutions to large decision problems using only low-dimensional analyses, since different combinations of dimensions can be critical to the evaluation results. Investigating all possible such combinations would lead to a procedure of high combinatorial complexity in the number of cases to investigate. Using hull cuts, such difficulties are circumvented. The evaluation idea behind the principle is to investigate how much the hull can be cut before dominance appears between the consequence sets compared. If there is no dominance even in the original core, it may be further cut towards the focal point in order to achieve dominance. The cut avoids the complexity inherent in combinatorial analyses, but it is still possible to study the stability of a result by gaining a better understanding of how important the constraint boundaries really are. By co-varying the cut of an arbitrary set of intervals, it is possible to gain much better insight into the influence of the structure of the decision frame on the solutions.

Consequently, a cut can be regarded as a focus parameter that zooms in from the full statement intervals to central sub-intervals (the core).

The results of the comparisons can be displayed either in a diagram for each pair of alternatives (Delta diagrams) or as a summary for each alternative (Gamma diagrams). Figure 4 below deals only with Delta diagrams.

In the figure, the evaluation of the three UTB scenarios is shown as three pairwise comparisons between the alternatives respectively. The x-axis shows the cut in per cent ranging from 0 to 100. The y-axis is the expected value difference δ_{ij} for the pairs. The cone (which need not be linear if comparative statements are involved) consists of three lines. For comparing alternatives A_1 and A_2, the upper line is max(δ_{12}), the middle is mid(δ_{12}), and the lower is min(δ_{12}). Thus, one can see from which cut level an alternative dominates weakly, markedly, and strongly. As the cut progresses, one of the alternatives eventually dominates strongly. The cut level necessary for that to occur shows the separability between the expected values.

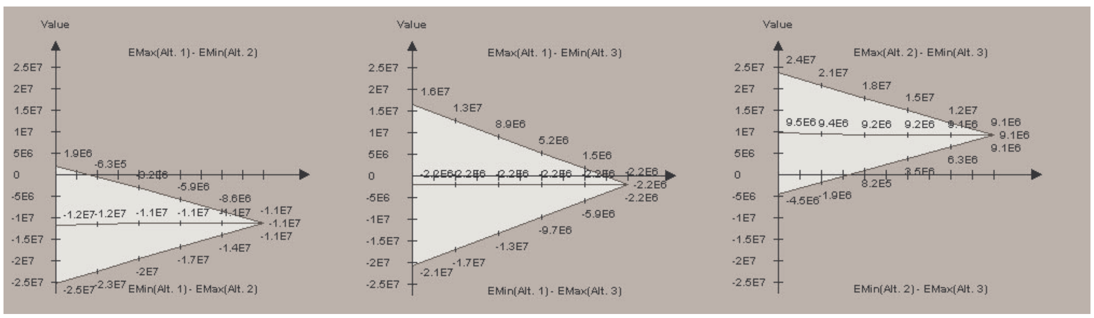


Figure 4: Evaluation of the UTB alternatives

Sensitivity Analyses

After the evaluation, a *sensitivity analysis* is the next step. The analysis tries to show what parts of the given information are most critical for the obtained results and must therefore be given extra careful consideration. This is accomplished by manually varying a number of statements in desired ways, increasing or decreasing intervals, modifying structural information, etc. The decision-maker might, however, have other ideas of interesting modifications to make to the bases, like decreasing or even increasing only selected intervals. He might have structural or problem specific information that leads him to manipulate certain intervals in special ways. A common strategy is decreasing intervals until only one alternative is admissible. It also points to which information is too vague to be of any assistance to the ongoing evaluation. Information identified in this way is subject to reconsideration, thereby triggering an iteration in the EDM process.

Decision Process Results

The selection procedure then continues with:

(i) Remove all strongly dominated consequence sets

(ii) If more than one consequence set remains

(ii a) Cut the frame until only one consequence set remains

(ii b) Remove the markedly dominated consequence sets

(ii c) A combination of (ii a) and (ii b)

(iii) If only one consequence set remains

(iii a) Uncut the frame until other consequence sets appear

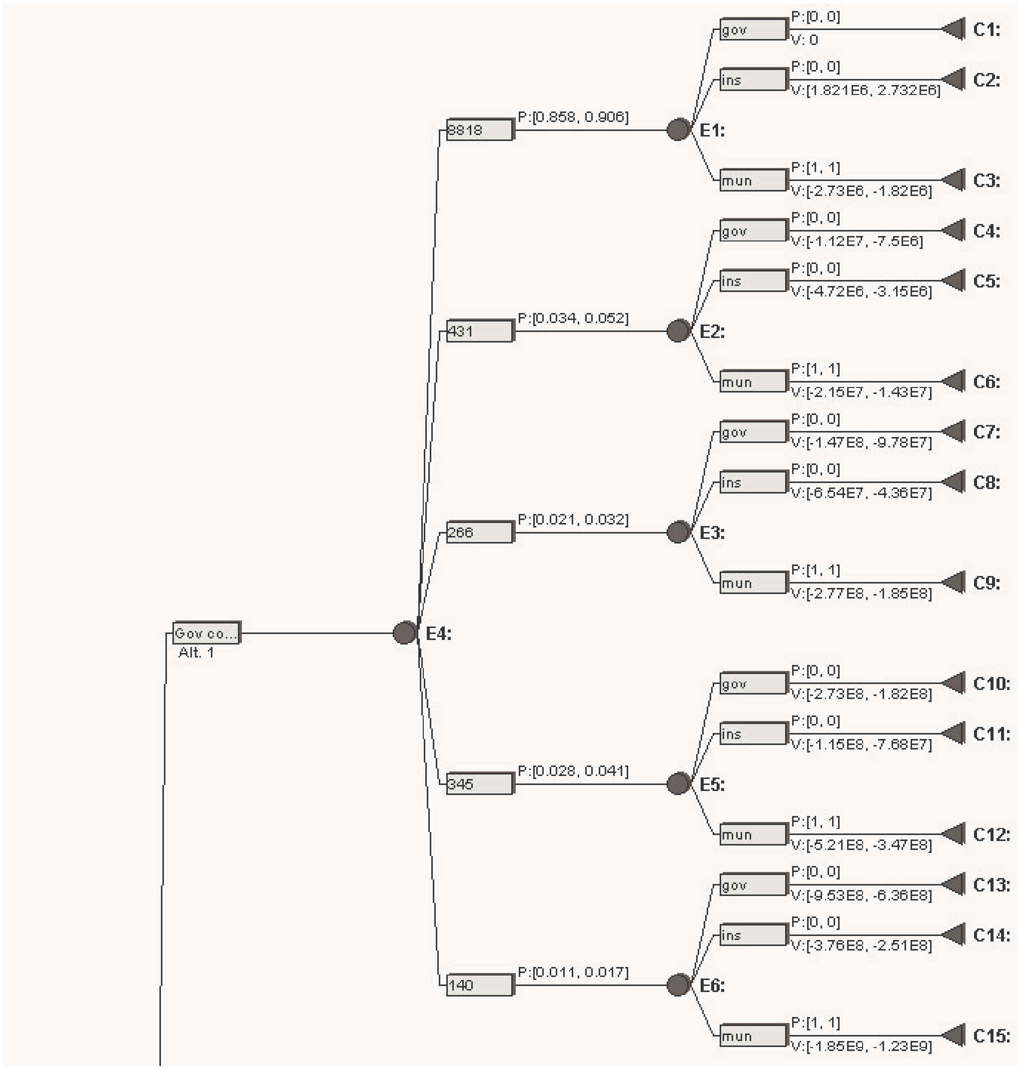
(iii b) Study the markedly dominated consequence sets

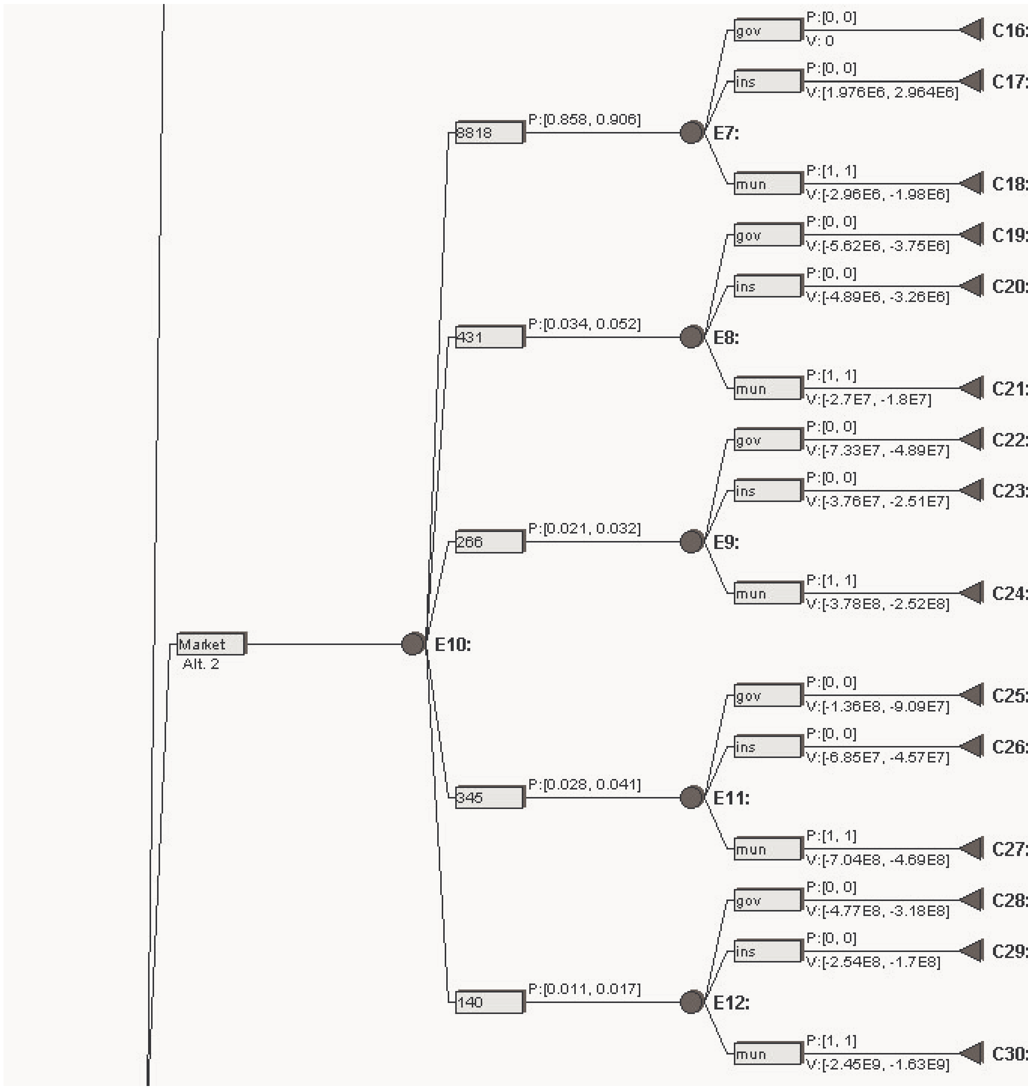
(iii c) A combination of (iii a) and (iii b)

Before a new iteration starts, alternatives found to be undesirable or obviously inferior by other information could be removed from the decision process. Likewise, a new alternative can be added, should the information gathered indicate the need for it. Consequences in an alternative can be added or removed as necessary to reflect changes in the model. Often a number of cycles are necessary to produce an interesting and reliable result.

After the appropriate number of iterations has been completed, both the decision problem and its proposed solution(s) in the form of preferred courses of action will be fairly well understood and documented. Anyone interested and with access to the information can afterwards check, verify (and criticize) the decision based on the output documentation, which because all consequences are clearly presented shows how all the alternative courses of action have been valued. Also, during the decision process, the analysis is open for comments and can become the basis for further discussions.

APPENDIX 6: DECISION TREE




Market
Alt. 2
E10:
8818
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E7:
gov
P:[0, 0]
V: 0
C16:
ins
P:[0, 0]
V:[1.976E6, 2.964E6]
C17:
mun
P:[1, 1]
V:[-2.96E6, -1.98E6]
C18:
431
P:[0.034, 0.052]
E8:
gov
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C19:
ins
P:[0, 0]
V:[-4.89E6, -3.26E6]
C20:
mun
P:[1, 1]
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C21:
266
P:[0.021, 0.032]
E9:
gov
P:[0, 0]
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C22:
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C24:
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C27:
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gov
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ins
P:[0, 0]
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C29:
mun
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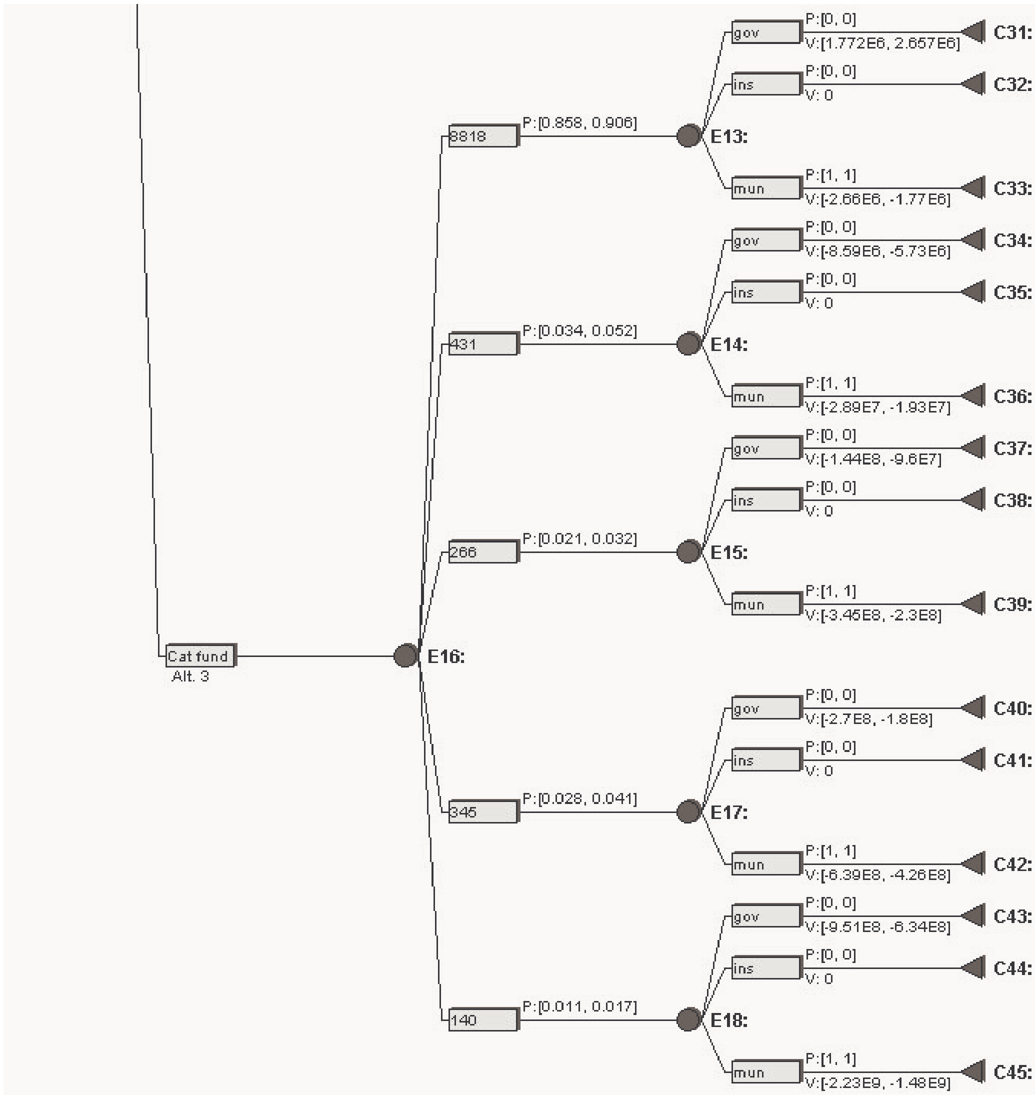
C30:



Cat fund
Alt. 3
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E13:
gov
P:[0, 0]
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C31:
ins
P:[0, 0]
V: 0
C32:
mun
P:[1, 1]
V:[-2.66E6, -1.77E6]
C33:
431
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E14:
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C34:
ins
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C36:
266
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E15:
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C37:
ins
P:[0, 0]
V: 0
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mun
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C39:
345
P:[0.028, 0.041]
E17:
gov
P:[0, 0]
V:[-2.7E8, -1.8E8]
C40:
ins
P:[0, 0]
V: 0
C41:
mun
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V:[-6.39E8, -4.26E8]
C42:
140
P:[0.011, 0.017]
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P:[0, 0]
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P:[0, 0]
V: 0
C44:
mun
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V:[-2.23E9, -1.48E9]
C45:

APPENDIX 7: DISSEMINATION

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