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.; these are fundamental parts of the natural, economic and social system wherever they occur. On 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 loss continues 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 concentrated 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 recognised that programs for creatively and effectively linking private and public responsibility, 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). Losses from floods are severe in this region, and costs for compensations 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. 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 organisations) that have to be taken into account. Consequently, there is a strong need for other loss sharing policies on 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 2001 and 2002, 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 judgements with this background as a component. Section 5 concludes the report. Finally, there is also a set of appendices. These consists in more elaborated descriptions of the flood simulation model and the decision analytical model as well as the 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 and the magnitude of a flood.. The shortcomings of statistical methods emphasises 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 are 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 seems 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 amount of possible scenarios makes the problem quite complex and not really suited for a more analytical treatment. This is particularly the case when also 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 4 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 is 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 use 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 compiled 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, 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 situation for all agents is 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 insurances. This choice affects the outcome both for the individual 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 form of premiums to 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 5.

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 company.
- 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
0,882	0
0,043	-9 372 425
0,027	-122 222 481
0,035	-227 255 130
0,014	-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 5. 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
0,882	2 276 800
0,043	-3 936 425
0,027	-54 470 117
0,035	-96 047 548
0,014	-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
0,882	-2 276 800
0,043	-17 932 566
0,027	-230 715 672
0,035	-434 214 423
0,014	-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 100 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 location subsidy 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
0,882	0
0,043	-4 686 212
0,027	-61 111 241
0,035	-113 627 565
0,014	-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
0,882	2 469 598
0,043	-4 074 660
0,027	-31 356 868
0,035	-57 104 532
0,014	-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
0,882	-2 469 598
0,043	-22 480 543
0,027	-314 940 162
0,035	-586 785 004
0,014	-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 insures 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 millions 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
0,882	2 214 540
0,043	-7 157 885
0,027	-120 007 941
0,035	-225 040 590
0,014	-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
0,882	-2 214 540
0,043	-24 083 531
0,027	-287 400 329
0,035	-532 476 511
0,014	-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 the appendix. 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. Further, the use of multi-level trees in this context 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.