Consensus by Simulation:
A Flood Model for Participatory Policy Making

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Abstract

In this article, we describe the design, implementation, and use of a flood simulation model, one of the activities n the Upper Tisza flood management project. The overarching goal of the project was to design a flood management policy that shifted part of economic disaster liability from the central government to individuals. The developed model was dynamic and spatially explicit, and it incorporated elements like micro-level representation and Monte Carlo techniques. It was also provided with an interactive graphical user interface; this addition changed the simulation model from a decision tool for a single expert user into a tool more suitable for decision-making in a participatory setting with multiple users. The model supported comparisons between predefined policy options as well as the design of new policy options. During a workshop that concluded the research project, the model was used interactively by the stakeholders in support of their decision making process; consensus was reached on a policy option that was designed during the workshop.

1 Background

It is hard to estimate the consequences of imposing new flood management policies; the outcome is a result of interacting natural, economic, political, and social systems. Recent interest in sustainable development and integrated assessment has demonstrated the need for holistic models in which natural systems are represented together with social and economic systems, and the interconnectedness between these systems is made explicit. A holistic approach often means that the problem under study becomes complex. When the merits and drawbacks of potential policy options are analyzed, it is hard to estimate the consequences on the real system. Instead, it is common to use a model to which the competing policy options are applied. Since the policies are intended to be applied in the future, it is not possible to decide the state on the system beforehand. One way of tackling this uncertainty is to evaluate the policy options under different possible future scenarios. The policy options must be evaluated many times to allow for a large variety of possible future scenarios. Modern computer techniques allow us to test systematically the uncertain variables such as water level or amount of precipitation, are assigned new random values for each simulation round. The simulation is repeated many times to ensure statistical reliability.

During the past two decades, spatially explicit catastrophe models have been used to quantify the risk of damage exposure, primarily by insurance and reinsurance companies [7, 11]. These models normally cover large geographic areas and use large amounts of property data and land data to calculate the effects of occurrences at different locations. Because of data intensity, the models are often aggregated by region or zip code. Micro models, on the other hand, represent each individual or household explicitly, that is, the objects in the real world correspond to the objects in the model in a 1:1 relationship. Models of this type are increasingly used in policymaking [13]. A micro model used for policy experiments outputs the effect of the new policy on each individual included in the model, allowing investigation of the distributional effects of new policies. A drawback of models that aggregate individuals is that the average outcome may hide inequalities; a policy that seems acceptable on average can be economically devastating to certain individuals. Fairness and equity between individuals, different societal groups, and different geographical regions are factors relevant for the acceptance of a new policy.

Several researchers have pointed out the need for a participatory approach to infrastructure planning, stressing the need for stakeholder involvement [16, 14]. When multiple stakeholders generate and exchange information, there is a need for common ground where different viewpoints may be discussed [19, 15]. According to Ramirez, it is important to support activities like reformulation and reexamination, and to promote ongoing adaptation during policy negotiations. The use of computer simulation models to support participatory decision-making on complex environmental issues was investigated in the ULYSSES and FIRMA projects [4, 5]. The results from these projects support the view that the use of computer models provides direct access to expertise, and that the interactive process supports understanding, learning, and decision-making.

In the Upper Tisza flood management project, the overarching goal was to design a robust, socially and economically acceptable policy for flood management that shifted part of the economic disaster liability from the central government to individuals. The real challenge was to fulfill both requirements: identify a policy that moves part of the economic burden to individuals, while still being socially and economically acceptable to all, or most, stakeholders. A flood simulation model was designed, implemented, and tested within the project. The purpose was to support the stakeholders when deciding on such a policy.

The flood simulation model combines the features of micro models and catastrophe models; it is a spatially explicit flood simulation model with disaggregated data at the level of households. Conceptually, it can be divided into four modules: the disaster module, the policy module, the consequence module, and the interface module. Section 2 presents the theoretical background of the simulation model, followed by a conceptual description of how the different modules interact. Section 3 provides a description of how the catastrophe events are generated in the model, and Section 4 shows how policy options are constituted and how they are tested on the simulation model. Section 5 provides a description of the economic update rules for the government, the insurance company, and the property owners. Section 6 describes the graphical user interface and the principles that governed the design of it. In Section 7, we describe how the simulation model was used during the final stakeholder workshop. Our conclusions are presented in Section 8. For further descriptions of the simulation model, see Brouwers *et al.* [2, 3], Brouwers [1], and Ekenberg *et al.* [6].

2 Model Description

Simulation models with a predictive characteristic are tailored to answer questions of the "what-if" type, that is, what state will the modeled system be in if certain events occur.

An explicitly stated goal for the Tisza project was to adopt an integrated participatory approach. To do this, the issues to be represented in the what-part of the model were identified through interviews and surveys with the involved stakeholders. Current research demonstrates the importance of eliciting stakeholder values and incorporating them into the design of new technology [8]. In the Tisza case, following the initial interviews [18, 12], four significant economic indicators were identified, representing values important to the main stakeholders. To ensure that comparisons could be made easily, it was important that all stakeholders have a common frame of reference, in this case monetary outcome. Other, subjective factors, such as the emotional attachment to a house, would be more difficult to quantify, and to incorporate into the simulation model. Therefore, such factors were not considered in this pilot project. The only factor of interest in this case was the economic consequences of imposing a new flood management policy. The consequences should ideally be presented from the perspectives of the various stakeholders; those of the government, the insurer, the pilot basin, and the individual property owner. The indicators and the wealth transformation functions are described in Section 5.

The if-part was composed of two events: flood state and choice of policy option. These two if-parts were conceptually very different in the model. The flood state was truly stochastic, represented as an uncontrollable natural process, while the choice of policy was a controllable parameter. Before the start of a new simulation, the users had to choose between applying a predefined policy option and designing a new policy. Only policies comprising non-structural financial measures were implemented in the model. The main reason for this limitation was that estimates of costs and consequences of imposing other types of mitigation measures, like heightening the levees or building an emergency reservoir, were very uncertain and considered beyond the scope of this pilot project.

Since micro-level data was available for each household in the pilot basin, the data was kept disaggregated to facilitate analysis at the household level. A simulation approach was chosen over finding analytical solutions, since the system under study is complex and stochastic. The stochastic processes operate both at the macro level (levee failures) and at the micro level (distribution of insurance contracts and of poverty). The stochasticity at the macro and micro level in combination with the dynamic property of the model make the space of possible simulation outcomes very large. The basic time-step in the simulation model is one year, and one simulation round consists of one, five, or ten successive years. A complete simulation consists of 500, 1 000, or 10 000 iterated simulation rounds.

During a simulated year, the system can be in one of ten possible flood states (for details, see Section 3). If a 10-year period is simulated, the number of possible outcomes is 92 378 (19!/9!10!) for each policy option. It makes a difference when a levee failure occurs; the two time series of flood states [0,0,0,0,0,0,0,0,0,5] and [0,5,0,0,0,0,0,0,0,0] are different. In the first series, the insurance company has accumulated a financial risk reserve over nine years (collected premiums) when the levee failure occurs, while the risk reserve would be much smaller in the second series, which implies a greater risk of insolvency.

The number of possible outcomes only takes flood states into consideration; it would be considerably larger if insurance and poverty distributions were included.

The studied river basin occupies an area of 107 km^2. The basin lies in the Szabolcs-Szatmár-Bereg County (area approx. 5 900 km^2), located in the north eastern corner of Hungary. This county borders on Romania, Slovakia, and Ukraine.

In the model, the basin is geographically represented in form of a grid, consisting of 1551 $\times$ 1551 cells, each side measuring 10 m. There are 2 580 properties in the basin, located in 11 municipalities.

The simulation model consists of the following modules: the disaster module, the policy module, the consequence module and the interface module. The disaster module determines what flood state the system will be in each simulation year. The governing flood management policy is specified in the policy module, that is, the values are set for policy variables such as price of premiums and level of post-disaster compensation from the government. The economic outcome for the different stakeholders represented in the model is updated annually in the consequence model. The interface module provides the users with a graphical interface to communicate with the policy module and display results generated by the consequence module.

3 Disaster Module

In an unprotected river, all floods would overtop the embankments; floods would be more frequent and smaller. However, since the part of the Tisza River that was modeled is protected by levees, only levee failures were considered. A levee failure occurs when a levee fails to hold back the water, that is, it breaks or the water overtops the levee. The uncertain nature of the river is represented in the model by dynamically changing the flood state of the system.

Hungarian hydrologists at Vituki Consult Rt. [17] calculated the probabilities for nine plausible levee failure scenarios. The nine scenarios are based on the assumption that a levee failure can occur at one of three geographic locations, and that the flood has one of three magnitudes (100-year flood, 150-year flood, and 1000-year flood). The combination of location and magnitude gives nine failure scenarios, the flood states the system can be in. The tenth and complementing state is the zero-event when no levee failure occurs.

The probabilities that floods of different magnitude will occur any single year are defined as 0.01 for a 100-year flood, 0.0667 for a 150-year flood, 0.001 for a 1 000-year flood and 0.9823 $(1-(1/100+1/150+1/1\,000))$ for no flood. If there is a flood, then one of two possible things can happen: the levee holds back the water (no levee failure) or the levee fails since it is overtopped or it bursts. The probabilities of levee failure at three locations are presented in Table 1.

Location:	1	2	3
Levee failure from 100-year flood	0.12	0.20	0.28
Levee failure from 150-year flood	0.18	0.22	0.40
Levee failure from 1000-year flood	0.19	0.33	0.45

Table 1: Failure probabilities, numbers from Vituki

Since it is impossible to tell when a flood or a levee failure will occur, Monte Carlo techniques were used to determine the state of the system. Each simulated year, the stochastic variable *flood* is assigned a random number in the range $0 - 1$ from a uniform distribution. The value is checked against nine threshold-values. If the value is <= 0.0012 scenario 1 occurs, (failure at location 1 from a 100-year flood), if it is <= 0.0032 scenario 2 occurs (failure at location 1 from a 150-year flood), and the check against thresholds continues until 0.0123 for the ninth scenario. If the value is greater than this, scenario 10 (no failure) occurs. The probability of a failure is obtained by the compound probability of the flood and the failure. For instance the probability of a levee failure at location 3 from a 1000-year flood' is 0.00045 (0.001×0.45).

4 Policy module

Designing new policies for the future and modifying predefined policies is an exploratory task. Since it would be impossible to consider all possible flood management policies that could be applied, the number of policies had to be reduced. A common way to do this is to lift out a subset of important policy parameters from the futures, and design plausible future *scenarios* where the values of these parameters differ. This approach was, for instance, used by the Intergovernmental Panel on Climate Change (IPCC) when they developed a set of long-term emission scenarios describing how greenhouse gas emissions might evolve between 2000 and 2100 [9].

The scenarios formulated in the Tisza case are referred to as policy options, and are based on the answers that were collected during the initial stakeholder interviews and surveys. The policy options described below reflect the widespread stakeholder support for continuing large-scale government involvement in a national insurance program with post-disaster relief for flood victims, as well as for the simultaneous introduction of individual responsibility and insurance. The three predefined policy scenarios that were simulated with the model at the stakeholder workshop are described in Linnerooth-Bayer *et al.* [12], but are summarized below.

- Policy Option A1: a mixed public private system
  - insurance premiums are flat-rated (cross subsidised)
  - holders of insurance receives 50 per cent post disaster compensation
  - government offers 50 per cent post disaster compensation and subsidises (part of) premiums for poor households
- Policy Option B1: private responsibility and insurance

  - risk-based premiums
  - coverage varies between 30 and 100 per cent
  - government offers no post disaster compensation, but subsidises (part of) premiums for poor households
  - government re-insures insurer

- Policy Option C1: mandatory public insurance
  - public insurance scheme - no private insurers
  - flat rated 'premiums' (new mandatory property tax)
  - government offers 100 per cent post disaster compensation and subsidises (part of) property tax for poor households
  - government underwrites all risks (acts as re-insurer)

During the workshop a desire to modify the pre-defined policies and design new policies emerged. This activity was supported by the simulation tool, since it allowed for interactive design of new policies by setting a number of parameters such as *premiumsize* and *level of compensation.*

5 Consequence Module

The economic outcome was presented from three perspectives:

- Government
- Insurance company
- Property-owners (one single property owner and one aggregated outcome for all property-owners in the entire pilot basin)

For each of these stakeholders, the policy-relevant parts of their economy were updated annually. The outcomes were saved after each simulated 10-year period. The total outcomes were analyzed after an entire simulation, which consisted of 1 000 10-year periods.

The outcome from a 10-year period was not merely the result of the flood states and the governing policy; before each simulation round it was randomly decided whether or not each property had an insurance policy. The overall proportion of insured households was either already decided in the three policy options (see Section 4), or it was decided interactively through the graphical user interface. There were 2 580 properties, which yields $2^{2\,580}$

possible outcomes of a binary insurance choice (insured/not insured). The insurance distribution stayed fixed over a 10-year period.

Approximately 60 per cent of the households in the region were considered poor [10]. In the simulation model, this affects to what extent the government subsidizes the insurance premiums for the property owner. Since we did not have access to micro data on income, we reduced the income variability to two states: poor or non-poor. The poverty distribution stayed fixed during a simulation round, and it did not affect the likelihood of buying insurance coverage.

5.1 Damages

$$\mathrm{ScenDam_i} = \sum_{\mathrm{j=1}}^{2\,580} \mathrm{ScenDamProp_{i,j}} \tag{1}$$

For each of the ten levee failure scenarios i (nine with failures and one without) there is a corresponding damage distribution for each property j. In equation 1, *ScenDamProp* is the economical damage distribution for each failure scenario and each property.

$$\mathrm{ScenDamMun_{i,j}} = \sum_{\mathrm{k=1}}^{2\,580} \mathrm{IsInMun_j(k)ScenDamProp_{i,k}} \tag{2}$$

The total damages from a levee failure scneario i in the municipality j are described in equation 2. The function $IsInMun$ returns 1 if property owner k lives in municipality j, otherwise 0.

$$\mathrm{ExpIndDam_i} = \frac{\sum_{\mathrm{j=1}}^{10} \mathrm{ScenDamMun_{i,j}ProbDam_j}}{\mathrm{NoPropOwners_i}} \tag{3}$$

Equation 3 calculates the average expected damages for an individual property owner located in municipality i. The premium of the risk-based insurance is based on the local risk, that is, the expected damage per municipality. $ProbDam$ is the probabilty that failure scenario j occurs. See equation 8 for determination of risk-based premiums.

5.2 Government

$$\mathrm{TotGovSubs} = \sum_{\mathrm{i=1}}^{2\,580} \mathrm{IsPoor(i)InsPrem_iSubsLevel} \tag{4}$$

The government subsidises part of the flood insurance premium for poor households. The function *IsPoor* returns true (1) or false (0). *InsPrem* is the size of the flood insurance premium, which the property owner pays to the insurance company. *SubsLevel* is the level to which the government will subsidise the insurance premium for a poor household.

$$\text{TotGovComp} = \text{GovCompLevel}(\sum_{\text{i=1}}^{11} \text{AllDamMun}_{\text{i}}) \tag{5}$$

After a levee failure, the government compensates the owners of the flooded properties to a certain percentage of the damages. Equation 5 calculates the amount of governmental compensation, *GovCompLevel* is the fraction of the damages that the government will compensate for. *AllDamMun* is the total damages (from all failure scenarios) for the municipality i.

$$\text{GovBalance(t+1)} = \text{GovBalance(t)} - \text{TotGovSubs} - \text{TotGovComp} \tag{6}$$

Equation 6 is the dynamic update-rule for the economic balance of the government, t represents the current year in the simulation. At t=0 $GovBalance = 0$.

5.3 Insurance agent

$$\text{TotInsPremFR} = \sum_{\text{i=1}}^{2\,580} \text{PropVal}_{\text{i}}(\text{1-Deductible}_{\text{i}})\text{PremSize} \tag{7}$$

In equation 7, the insurance company receives incomes from insurance premiums, see equation 11 how the size of the flat-rated premium is decided. *PropVal* denotes the value of property i. *Deductible* is the fraction of property i that is uninsured. *Premsize* is the size of the flat-rated premium. Consider for instance the following policy: the premium size for a flood policy is 0.1 per cent of the property value, and the deductible is 20 per cent, then the annual premium for a policy insuring a property worth 200 000 USD would be 160 USD.

$$\text{TotInsPremRB} = \sum_{\text{i=1}}^{2\,580} \sum_{\text{j=1}}^{11} \text{IsInMun(i)ExpIndDam}_{\text{j}} \tag{8}$$
$$\text{(1+SafetyLoading)(1-Deductible}_{\text{i}})$$

Equation 8 describes how the risk-based premium is calculated. For each property owner, the expected damages (based on current municipality, see equation 3) are multiplied with the $SafetyLoading$ (the insurer's add-on) and the coverage for that property $(1 - Deductible)$.

$$\text{TotInsComp} = \sum_{\text{i}=1}^{2\,580} \text{PropDam}_\text{i}(\text{1-Deductible}_\text{i}) \tag{9}$$

The insurer compensates the policy holders who suffer damages from a peril they are insured against. In equation, 9 the total amount of compensation the insurer has to pay is described. For each policy holder who has experienced damages, the compensation depends on the size of the damages and the level of the deductible. Assume that the damages for a property summed to 10 000 USD. If this policy had a 30 per cent deductible, then the property owner would receive 7 000 USD in compensation: size of damage×(1-deductible).

$$\begin{aligned}\text{InsBalance(t+1)} = \text{InsBalance(t)} + \text{TotInsPremFR+} \\ \text{TotInsPremRB} - \text{TotInsComp}\end{aligned} \tag{10}$$

A year when a flood has occurred, the insurers will compensate the policy holders according to the size of the damages and the level of deductibles. Equation 10 displays the wealth transformation over time for the insurance company.

5.4 Property Owners

$$\begin{aligned}\text{PremFR}_\text{i} = \text{PropVal}_\text{i}(\text{1-Deductible}_\text{i})\text{PremSize} \\ \text{[1-(IsPoor(i)(SubsLevel))]}\end{aligned} \tag{11}$$

Equation 11 describes how the size of the flat-rated insurance premium for property owner i is decided. A poor property owner only pays part of the insurance premium, the other part is subsidised by the government.

$$\begin{aligned}\text{PremRB}_\text{i,j} = \text{ExpIndDam}_\text{j}\text{(1+SafetyLoading)}(\text{1-Deductible}_\text{i}) \\ \text{[1-(IsPoor(i)(SubsLevel))]}\end{aligned} \tag{12}$$

The size of the risk-based insurance premium for property owner i is described in equation 12, based on the expected average damage for the municipality j.

$$\text{GovSubs}_\text{i} = (\text{PremFR}_\text{i} + \text{PremRB}_\text{i})\text{(IsPoor(i)SubsLevel)} \tag{13}$$

The level of governmental subsidation for insurance premiums (flat rated and/or risk based premiums) is described in equation 13.

$$\text{PropComp}_\text{i} = \text{PropDam}_\text{i,j}(\text{1-Deductible}_\text{i}) + \text{PropDam}_\text{i}\text{GovCompLevel} \tag{14}$$

In equation 14 the insurance compensation plus the governmental compensation to the property owner i is described. One of the ten possible levee failure scenarios j occurs each year.

$$\begin{aligned}\mathrm{PropBalance_i(t{+}1)} = \mathrm{PropBalance_i(t)} - \mathrm{PremFR_i} - \mathrm{PremRB_i} \\ +\mathrm{GovSubs_i} + \mathrm{PropComp_i}\end{aligned} \tag{15}$$

The dynamic balance of the property owner agent i is described in equation 15.

$$\mathrm{PilotBalance(t{+}1)} = \mathrm{PilotBalance(t)} + \sum_{\mathrm{i=1}}^{2\,580} \mathrm{PropBalance_i(t)} \tag{16}$$

The Pilot balance in equation 16 is calculated by aggregating the balance of all property owners.

6 Interface Module

Usability was an essential aspect. All users with the relevant background knowledge regarding floods in the investigated area should be able to interact with the model, regardless of computer skills. It was important to stimulate and engage all participants in spite of the limited time setting, that is, we made an interface that was easy to learn in a short time a priority. Ideally, the economic consequences for the different policy options would be presented in an unbiased fashion, taking into account as many of the potential stakeholder objectives as possible. Two things were accomplished by allowing stakeholders to easily view outcomes resulting from specific parameter settings: We refuted misconceptions regarding the importance of individual parameters and confirmed that the value range of specific parameters was acceptable to the users involved .

The main considerations at the beginning of the design of the GUI were to decide which variables from the model to make available to users. We had to weigh the pros and cons of exposing each model variable, and decide whether to hide a variable at the cost of compromising transparency, or make it accessible at the risk of jeopardizing the easy-to-use interface. Since we were trying to support the exploration of possible consequences of applying different policy options, the policy variables were made more explicit (for example, *insurance rate*, *premium size*, and *level of government compensation*). To simplify the input procedure and make it more suitable for collaborative work, interaction with the model was accomplished by mouse input, choosing values from pop-up menus, dragging sliders, or choosing radio buttons.

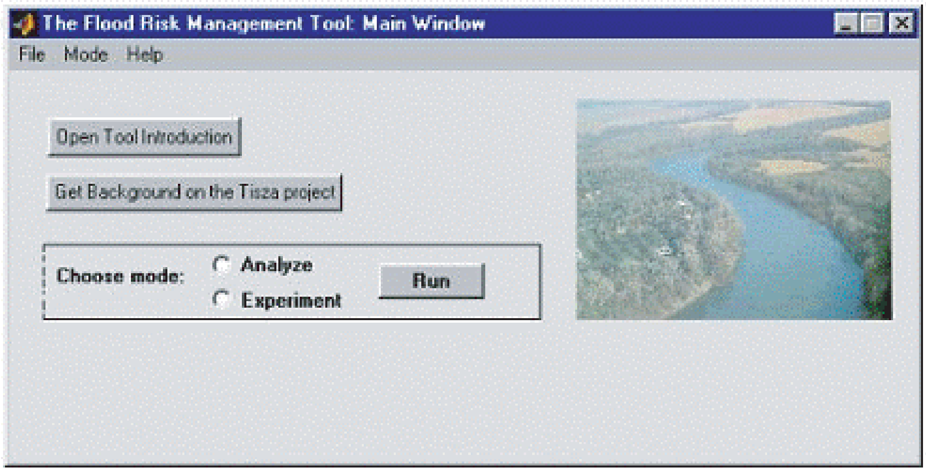

Figure 1: The Main Window.

Results from similar projects, for example, the ULYSSES project [4], show that participants prefer such input procedures. Also, this increases process awareness for the whole group (and not just for the person in control of the keyboard) as everyone can follow the course of events and view possible options.

A windowing system approach was used for the simulation model. The different steps of in the simulation procedure resulted in a natural division of interaction with the model into three stages: choose a mode; set variables; and view results.

6.1 The Main Window: Choose a Mode

The flood simulation model can be used in two separate modes: the Analyze Mode (analysis of the three predefined policy options) or the Experiment Mode (design of new policy options). Figure 1 shows the main window of the model (the user interface), where the user can choose to open the "settings" window for either of the two modes.

6.2 Settings Windows: Set Variables

When simulating policy options, the user has the option of choosing the number of simulated years, the number of times to repeat the simulation (number of simulation rounds), and whether to let the flood frequency have the current rate or to increase/decrease it.

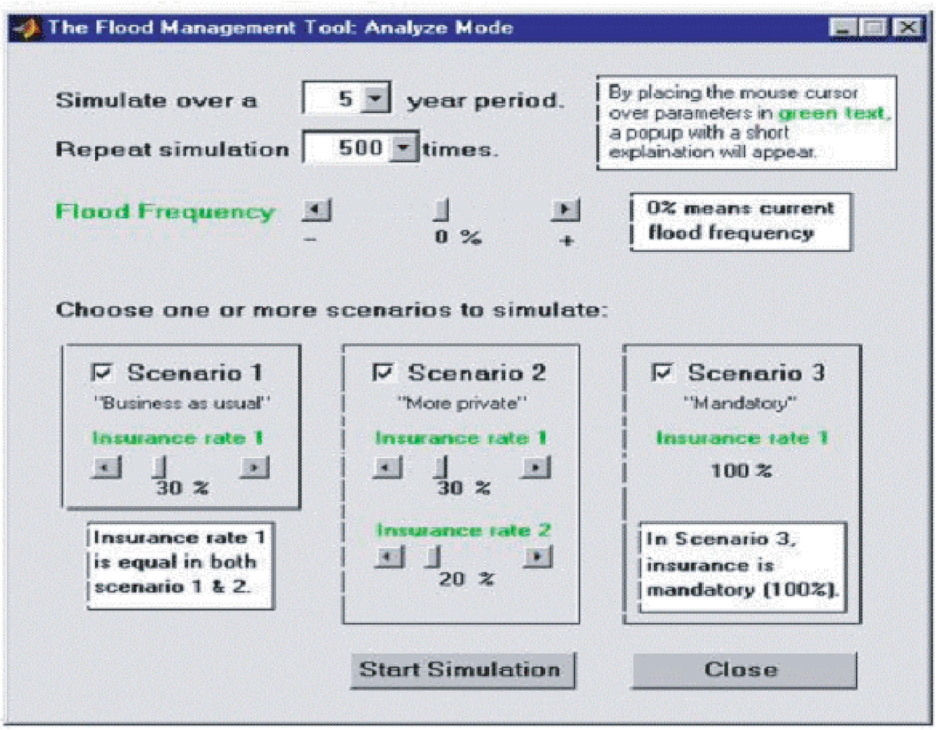

Figure 2: The settings window for the Analyze Mode.

Each mode has its specific purpose. The Analyze Mode is a direct implementation of the three proposed flood management policies, options A1, B1, and C1 [12], here referred to as scenarios 1, 2, and 3. In the settings window of the Analyze Mode, the user can choose which scenario(s) to include in the simulation. The user can set the values of the parameters for insurance rates, that is, the fraction of all households that have *insurance 1* and *insurance 2*.

The Experiment Mode was designed to support exploratory processes where users can modify existing policies and design new ones (up to three at a time). In the settings window of the Experiment Mode, the users design their own policy options by setting a group of parameters, namely *Yearly Income*, *Insurance Rate 1*, *Insurance Premium 1*, *Compensation from Insurance 1*, *Insurance Rate 2*, *Compensation from Government*, *Government Acts as Reinsurer*, and *Flood Tax*.

6.3 Results Window: View Results

After each simulation, the results are displayed in a common view. The user can view the results from one of the four stakeholder perspectives at a time,

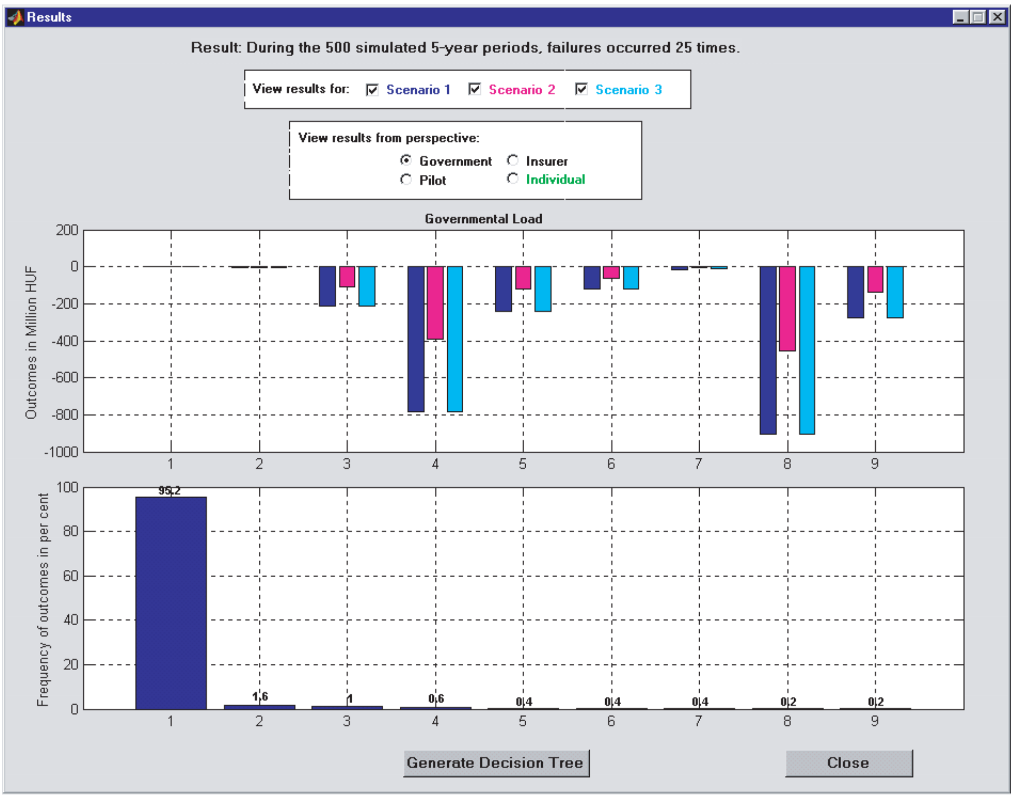

Figure 3: The Results Window. The top graph shows the different types of outcomes resulting from the simulation. The bottom graph shows the corresponding frequency of each type of outcome.

and also switch between displaying one, two or three simulated scenarios simultaneously. Results corresponding to each perspective are displayed in two graphs (see Figure 3). The top graph shows the different economic outcomes resulting from the simulation, whereas the lower graph shows the corresponding percentage of each outcome, that is, the number of times that each outcome occurred out of all repetitions of the simulation. This view enables the user to compare relatively easily the different policy options; for example, in the majority of the outcomes (95.2 per cent) the government has 0 florins (HUF) in expenses in scenarios 1, 2 and 3, but in the most extreme case (0.2 per cent of the outcomes) the government has a loss of over 400 million HUF for scenario 2, and in the case of scenarios 1 and 3, a loss of 900 million HUF.

7 Stakeholder Workshop

In line with results from similar projects such as ULYSSES [4], the final stakeholder workshop was moderated by two experts, one group moderator and one model moderator. The group moderator (whose mother tongue was Hungarian but who was fluent in English) guided the discussions during the workshop, and the model moderator guided the specific discussions during the computer interaction phase. Initially, the model moderator presented the simulation model briefly to clarify the meaning of simulations, some of the terms used, and how to interpret generated results.

The stakeholders (representatives from different interest groups) were divided into three groups depending on which of the three predefined policy options they preferred. After discussions [12], the whole group reached consensus on a new acceptable scenario (Policy Option D), and the final design of it was made on screen interactively using the Experiment Mode:

- Policy Option D: Consensus Option
  - flat rated (cross subsidised) insurance premium
  - holders of insurance contract receives 50 per cent post disaster compensation
  - government offers 50 per cent post disaster compensation - but only to insured households
  - government subsidises (part of) insurance premium to poor households
  - government does not re-insure insurer

After viewing the results, there was an open discussion of the results and of the use of the simulation model. The participants had a positive attitude toward using such a tool in future discussions on policies.

8 Conclusions

The Tisza pilot study showed that a participatory decision-making process can be enhanced in several ways by enabling the main stakeholders to interact with a flood simulation model. The complexity of the simulation model could have inhibited user understanding and involvement in the informed decision-making process; instead, the design of the tool provided them with a useful and logical basis for comparison and discussion. Users were able to argue for their opinions and easily express them as policy options during discussions.

The group as a whole could interactively explore different insurance policies and compare settings and their corresponding results. The interactive process during the workshop added to overall awareness within the group, which is important when making an informed decision and attempting to reach consensus.The views and suggestions of others as well as possible effects of implementation were more transparent because all participants used the same means of evaluation and presentation. In spite of initially conflicting opinions, active stakeholder involvement eventually led to agreement on an acceptable policy option.

Our expectation is that a tool like this could be used by more people and that the use of simulation models could empower them during a decision process. Allowing decision-makers to access and explore decision data in a more transparent manner, may lead to a greater acceptance of the final decision. In addition, it may be considered a more democratic way of making decisions that affect a large number of people, given that the users represent the population that is immediately affected by the decisions in question. However, there is a need for more thorough studies on its usefulness under these circumstances

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