Design of Flood-loss Sharing Programs in the Upper Tisza Region, Hungary:

A Dynamic Multi-Agent Adaptive Monte Carlo Approach

Tatiana Ermolieva, ermol@iiasa.ac.at, International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria, Tel.: (+43 2236) 807 581

Yuri Ermoliev, ermoliev@iiasa.ac.at, International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria, Tel.: (+43 2236) 807 208

Joanne Linnerooth-Bayer, bayer@iiasa.ac.at, International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria, Tel.: (+43 2236) 807 308

Anna Vari, anna.vari@ella.hu, Hungarian Academy of Sciences, Budapest, Hungary.

Aniello Amendola, amendola@iiasa.ac.at, International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria, Tel.: (+43 2236) 807

Abstract

Losses from human-made and natural catastrophes are rapidly increasing. The main reason for this is the clustering of people and capital in hazard-prone areas as well as the creation of new hazard-prone areas, a phenomenon that may be aggravated by a lack of knowledge of the risks. This alarming human-induced tendency calls for new integrated approaches to catastrophic risk management. This paper demonstrates how flood catastrophe model and adaptive Monte Carlo optimization can be linked into an integrated Catastrophe Management Model to give insights on the feasibility of a flood management program and to assist in designing a robust program. As a part of integrated flood risk management, the proposed model takes into account the specifics of the catastrophic risk management: highly mutually dependent losses, the lack of information, the need for long-term perspectives and geographically explicit models, the involvement of various agents such as individuals, governments, insurers, reinsurers, and investors. Therefore, the integrated catastrophe management model turns out to be an important mitigation measure in comprehending catastrophes. As a concrete case we consider a pilot region of the Upper Tisza river, Hungary. Specifically, we analyze the demand of the region in a multipillar flood-loss sharing program involving a partial compensation by the central government, a voluntary private property insurance, a voluntary private risk-based insurance. GIS-based catastrophe models and specific stochastic optimization methods are used to guide policy analysis with respect to location-specific risk exposures. To analyze the stability of the program, we use economically sound risk indicators.

Introduction.

Losses from weather related extreme events are rapidly increasing (Climate Change and Increase in Loss Trend Persistence, 1999). The main reason for this is the clustering of people and capital in hazard-prone areas as well as the creation of new hazard-prone areas (National Research Council, 1999), a phenomenon that may be aggravated by a lack of knowledge of the risks. This alarming human-induced tendency calls for new integrated approaches to the land use and the catastrophic risks management. The importance of these approaches is especially evident in Hungary, where 23 percent of the country is endangered by riverine floods: only the Netherlands has a similar degree of risk, with 20 percent of the country under sea level.

Since 1998 Hungary, in particular, Tisza plain, has been affected by a number of severe floods: during the past 18 month almost all “flood records” have been beaten, in the 1999 year flood the water level from Tiszabecs up to Mindszent sections of the river have exceeded the highest level ever measured. In 2000 the flood caused such a loading on the protection system, which used to occur once in 500 years, while, according to the national regulations, the protection system had been constructed for a flood wave with a return period of 100 years. The flood wave threatened the entire Hungarian Great Plain, where the total installed wealth of national economy reached 2.900 billion HUF (www.oieau.fr/riob/ag2000), the number of the affected municipalities was 402, the number of the endangered population was 1454 thousands. The total cost of works to protect against moving water, which were implemented in 2000, reached 13,2 billion HUF. Development of the defenses to the prescribed level of flood safety in the areas exposed to potential inundation would require investment costs amounting to approximately 170 billion HUF. A realistic proposal was compiled for a ten-year development program under which levees of 740 km total length would be strengthened with an estimated cost of 60 billion HUF (Vituki Consult, www.vituki-consult.hu). According to the experts, currently it is not possible to improve situation with dikes along the whole river, and alternative programs for flood-loss sharing are being widely discussed (Proposal for the Project on Flood Risk Management Policy in the Upper Tisza Basin, 2000), (Vari et al., 2001, 2003).

This paper reports on the analysis of alternative loss-sharing programs involving governments (central and local), insurance, investors, individuals, etc. The numerical experiments emphases the necessity of a robust flood management program which would take into account constraints of involved parties and provide relieve against vast variety of floods. As a part of integrated flood-loss management, we estimate the demand of a pilot region in the Upper Tisza in insurance, subsidies, and direct governmental aid. With this purpose we developed a spatial dynamic multi-agent stochastic optimization model, which can guide policy makers and stakeholders in working out a loss-sharing program acceptable for a region with high risks and low incomes. The work presented is a part of the research study on “Flood Risk Management Policy in the Upper Tisza Basin: A System Analytical Approach” conducted at IIASA. This article includes some earlier results from the work on “The Role of Financial Instruments in Integrated Catastrophic Flood Management “ (Ermolieva et al., 2001).

Since catastrophes are rare events and there may be not enough data to estimate potential losses due to a disaster at a particular location for making decisions on the direct compensation by governments, the allocation and values of contracts, premiums of insurers, reinsurance arrangements, and effects of mitigation measures, the catastrophe modeling (see Walker, 1987) is becoming increasingly important. Such models compensate for the lack of historical data on the occurrence of catastrophes in locations where the effects of catastrophes may have never been experienced in the past. The reported model incorporates a river and an inundation modules to calculate property losses due to floods. Analysis of different catastrophic scenarios may lead (in general) to different decision strategies, thus corresponding to a rather straightforward “if-then” approach. The important question is how to find a decision strategy, which is the "best", in a sense, against all possible scenarios. In papers (Amendola et al., 2000, 2000a, 2001, Ermoliev et al., 2000, 2000a, 2000b, 2001, Ermolieva, 1997, Ermolieva et al., 1997, 2002), it was shown that the search of "robust" optimal decisions can be done by combining stochastic optimization techniques with catastrophic modeling (Adaptive Monte Carlo optimization). By using this approach it is possible to take into account complex interdependencies between damages at different locations, decisions and resulting losses and claims. Presented model incorporates all these features.

Section 1 summarizes stakeholders views on the flood management in the region and formulates feasible policy scenarios for a potential flood-loss sharing program, selected according to the interviews conducted with stakeholders in the Upper Tisza region (Vari et al., 2003). Section 2 discusses main characteristics of a GIS-based catastrophe model able to simulate samples of dependent potential losses and gains of agents for different policy scenarios. It outlines the methodology of a multi-agent, spatial and dynamic stochastic optimization model. The model emphasizes importance of cooperation between various agents (risk sharing institutions and individuals) in dealing with catastrophes (Amendola et al., 2001, Ermolieva et al., 2001) and, in general, the need for the coexistence of anticipative ex-ante and adaptive ex-post policies (Froot, 2000). Selected numerical experiments are described in Section 3. They indicate that premiums of the private flood-related insurance estimated based on expected losses may be too high for individuals what may decrease demand for catastrophe insurance. This calls for evaluation of coverage and premiums, which do not result in overpayments by individuals, satisfy individual income constraints, and guarantee solvency level to the insurer (the so-called robust premiums). The calculation of such premiums requires proposed stochastic optimization techniques. Section 4 concludes.

1. Stakeholders Views on Alternative Food Loss Sharing Programs.

With escalating costs of flood mitigation and relief, the risk management challenge is to develop a flood mitigation and insurance/relief system that is viewed as efficient and fair by the many stakeholders involved[1]. In Europe, Hungary ranks only behind the Netherlands with respect to flood exposure. Over half of the country's territory, two-thirds of its arable land, and a third of its railways are exposed to riverine, ground water and flash floods. Estimates show that losses from flooding could reach almost a quarter of the GDP of river flood basins, or 7-9 percent of the total GDP of the country (Halcrow, 1999**)**. One of the highest flood-risk areas in Hungary is the Upper Tisza river basin in the northeastern part of the country. The intensity and frequency of flood disasters in this region, and throughout Hungary, appear to be increasing because of development and farming practices in the exposed areas, deforestation and other land-use practices, the regulation of the rivers and neglect of the drainage systems (Gábor, 2000). Worsening weather extremes due to climate change may also be a contributing factor.

With increasing losses, the Hungarian government is concerned about continuing its tradition of taking almost full responsibility for flood risk management, including flood prevention, response, relief and public infrastructure repair. The central government has invested huge sums in a vast network of protective dikes, including about 3000 kilometers of dikes along the Tisza River. Without these dikes there would be extensive flooding in the country, for example, a flood occurring on the Tisza River could inundate up to 16,000 km^2 or around 17 percent of the territory of Hungary (Ministry of Transportation and Water Management, 2001). This dike system is proving insufficient with worsening flood conditions, and it is expensive to maintain. Moreover, there are value conflicts, for example, whether to continue protecting the residents of high-risk areas with dikes or to re-naturalize the river to enhance the ecosystem.

The Hungarian government takes full responsibility for private damages in the event of a dike breach, and victims from all types of floods usually receive a great deal of public relief. This social solidarity with flood victims, which is typical of all the formerly socialist countries of Central Europe, has become a major concern to the Hungarian government since its adoption of a fiscal austerity program for European Union membership. Government officials would welcome more private responsibility in reducing and insuring flood losses; however, many Hungarians regard the transfer of liability for flood losses to citizens in very poor areas, such as the Upper Tisza region, as unfair. One of the more controversial issues in Hungary, and throughout Central Europe, is thus the respective role of government and private market in providing relief to flood victims.

To aid policy makers in designing a fair and efficient approach, the project elicited stakeholder views on flood risk management in the Upper Tisza basin, including views on appropriate means of reducing losses and for transferring the residual losses from the direct victims to taxpayers or an insurance pool. For this purpose, face-to-face, open-ended interviews were carried out with the

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[1] This project, "Flood Risk Management Policy in the Upper Tisza Basin: An Integrated Approach" is being carried out by IIASA in collaboration with the Hungarian Academy of Sciences (HAS) and Stockholm University. It is funded by the Swedish FORMAS. In particular, the authors wish to acknowledge the cooperation with Anna Vari and Zoltan Ferencz, from the HAS Institute of Sociology, and Istvan Galambos, VITUKI Consult, Budapest; they also contributed to a number of papers, on which this article is based (see references Ermolieva et al. 2001, Ermolieva et al. 2002, Vari et al. 2001, Linnerooth-Bayer and Vari 2002, Vari et al. 2003).

actively involved stakeholders. These included twenty-four persons representing central, regional and local government agencies, farmers and entrepreneurs, NGO activists and insurance companies. The interviews formed the basis for a public survey. A comprehensive questionnaire was used to elicit views of the public, that is, the less active stakeholders, on Hungary's options for reducing flood risks and providing relief to the victims.

A detailed description of the interview procedure, the policy options discussed, and their results is outside the scope of this paper (see for this Vari et al. 2001, Vari et al. 2003); however, for a better understanding of the integrated risk management concept for the project, it is useful to include selected results from the elicited views (see Tables 1 to 3).

To what extent do you agree with the following statements?	Fully agree %	Partly agree %	Disagree %	Do not know %
Social solidarity requires that government compensate flood victims for damages that occur to their homes and livelihood	48	41	7	4
Everybody should take more responsibility for flood risks and those who can afford it should purchase private insurance	40	50	6	4
Locals should pull together and create a fund which could help flood victims in case of a disaster	37	43	14	6
It does not matter what you do, flood victims will lose a lot	7	29	51	13

Table 1. Government Compensation, Insurance And Pooling (Vari et al 2001)

The results show a large emphasis on central government responsibility and government compensation of flood victims, which most stakeholders viewed as highly desirable. Social solidarity for flood victims was strikingly apparent. Therefore, a mixed public-private system for the provision of victim relief and reconstruction, which combines taxpayer support with private insurance, was overwhelmingly supported.

In what follows, we lay out three scenarios of a flood loss-sharing program in Hungary identified by stakeholders as potential for the Upper Tisza region, (Vari et al., 2003). In this way, the stakeholders' views were incorporated into the flood-catastrophe risk management modelling.

After a major flood, the Hungarian government should compensate …	Chosen by (%)
All victims by a certain percentage of their losses	57
All victims by the same amount, above which they can choose to have insurance	19
Only needy victims, that is, not owners of vacation homes or well	7
Only victims with flood insurance	3
Only victims who have not built their homes in high risk areas without a permit	4
No one	0

Table 2. Forms of Government Compensation to Flood Victims (Vari et al.2001)

How should households, businesses, and communities be encouraged to reduce flood losses?	Chosen by (%)
The local authorities should pass zoning regulations and strictly enforce them	80
The central government should make compensation after a flood contingent on loss-reducing measures before the flood	53
Insurance companies should offer lower premiums to households, businesses and communities that have taken pre-specified loss-reducing measures	39
Insurance companies should raise premiums of those living in high-risk areas to encourage people to leave and discourage people building their homes in these areas	14
The central government should compensate far less of the losses from a flood	4

Table 3. Forms of Flood Loss Reduction (Vari et al. 2001)

1. 1. Policy Scenario 1. The first policy scenario for a Hungarian system is a continuation of what exists, or business as usual. The national government will continue to compensate victims for a percentage of their losses, and the amount of compensation will depend on the political climate and budget constraints. In the 2001 floods, the national government raised funds for this compensation by diverting from other budget expenditures (all ministries were required to contribute 2.8% of their budget). Not to run out of constraints, the government has to evaluate potential losses applying various techniques, in particular, catastrophe modeling, which nowadays becomes very popular for estimating alternative decisions in reduction and compensation of catastrophic consequences (Vituki Consult, www.vituki-consult.hu).

As shown in Figure 1, the first pillar of support for flood victims is thus government compensation. The second pillar, for floods caused by overtopping of dikes or breakage of the dikes, is private insurance. This is voluntary and bundled with property/fire insurance, and it offers the same premium to all persons in Hungary regardless of their flood risk. In this way, there will be cross subsidies from low-risk to high-risk households and businesses.

Because purchasers of insurance in high-risk areas are subsidized, this policy will *not* discourage persons from building in these areas and will, thus, raise the overall costs of flooding in Hungary. However, these flood policies may include a deductible, that is, the first percentage of the losses should be borne by the victims. In this way, persons, households and businesses at risk will have an incentive to take precautionary measures, such as heeding flood warnings and moving valuables to safe locations. Deductibles may be location-specific (for locations with distinguishable risks) or uniform. Estimation of deductible level at locations requires spatial (location-specific) profile of losses. Additional subsidies might be offered if communities take efforts to reduce the losses, e.g. by assuring that the drainage ditches are maintained and by preparing and enforcing a zoning plan.

The Hungarian government should regulate and control private insurers to make sure they have adequate capacity and reinsurance to remain solvent and pay claims even in the event of a series of large floods. However, the insurers should reinsure on the private market, the Hungarian government should not bail out insolvent insurers by acting as a "reinsurer of last resort".

1.2. Policy Scenario 2. In this scenario, the national government will continue to compensate victims, but for a smaller percentage of their losses. Again, the absolute amount of compensation will not be fixed by law but will depend on the political climate and political constraints. The purpose of this small amount of compensation is to assure that every victim has enough capital after the event to survive at a reasonable level. This amount will likely be less than the compensation offered in Scenario 1.

To make up the gap, all persons living in high-risk areas will have the opportunity to purchase subsidized insurance. However, this subsidized insurance will only be offered to cover a fixed percentage of losses. Persons wishing to purchase additional coverage can do so, but this additional insurance will not be subsidized. Rather, premiums will be based on the flood risks, that is, those in high-risk areas will pay substantially more than those in low-risk areas. Again, the government will not act as guarantee in the case of private insurer insolvency, but all insurance companies will be required to have sufficient funds and reinsurance on the private market to assure their policy holders a low level of risk.

1.3. Policy Scenario 3. The third policy scenario is based on the French system, where the national government does not compensate victims of natural disasters. Instead, *all* property owners are required to have property insurance, and an all-hazards insurance, covering fire, flood and other natural disasters, is a "bundled" part of this mandatory insurance package.

Low-income persons will be aided in the purchase of this insurance by the government. The premium will not depend on the risks of flooding, meaning that there will be cross subsidies from low-risk to high-risk insureds. The insurance policies will have a large deductible to encourage property owners to take measures to reduce their losses.

Instead of compensating victims, the government and taxpayers will contribute to the system as a "third pillar" (see Figure 1), that is, the government will reinsure the private insurance companies.

The private insurers will be required to pay a certain percentage of their premium income to the government, which will be allocated to a reinsurance fund. If insurers cannot cover the claims in the event of a flood or series of floods with very high losses, the policy holders will be reimbursed from the government fund. If the government fund is not sufficient, taxpayers will cover the deficit.

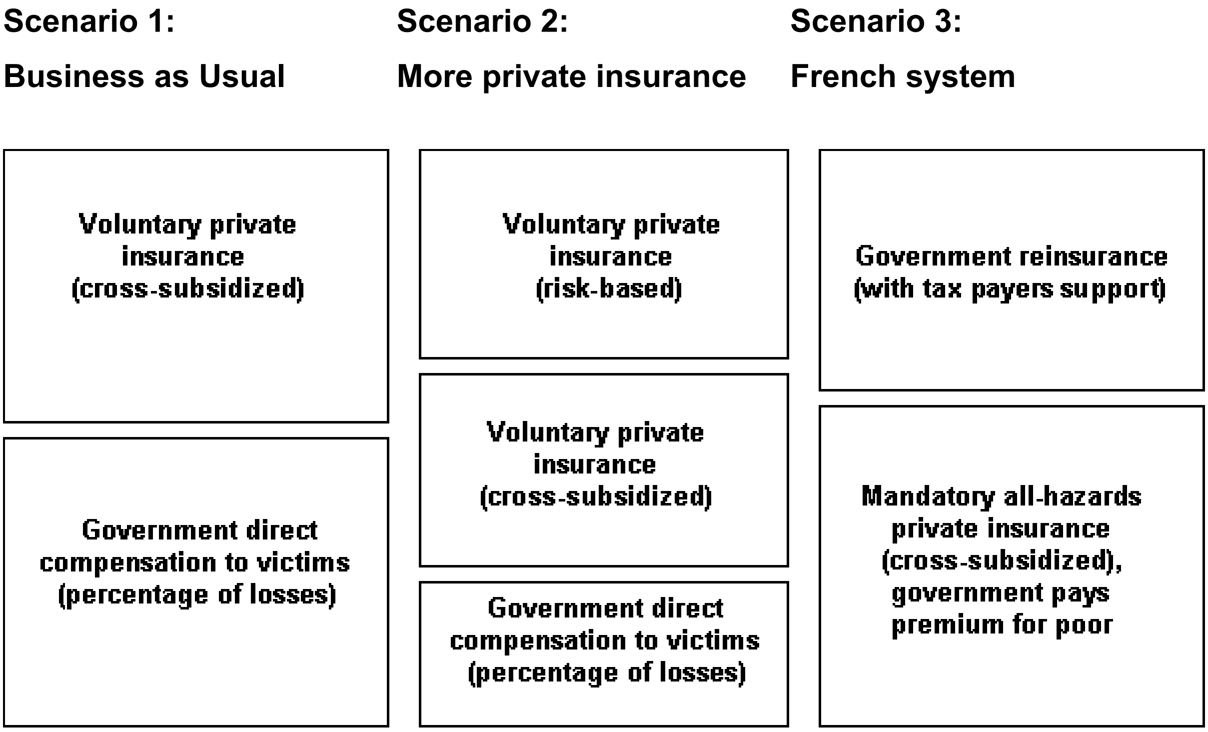

Figure 1. Alternative flood-loss sharing programs.

The further sections of the paper are devoted to the description of the modelling approach.

2. Outline of the Methodology

An adequate methodology must be able to take into account the specifics of the catastrophic risk management: geographically explicit models, highly mutually dependent losses, and the need for long-term perspectives in presence of uncertainties. As in the earthquake study case, a catastrophic flood generator is coupled with an Adaptive Monte Carlo optimization procedure, to investigate the feasibility of flood management programs.

The Integrated Model for catastrophic flood management consists of a “Catastrophe” model and a “Multi-Agent Economic Model”, (MAAS). The “River” module of the “Catastrophe” model calculates the volume of discharged water into the pilot region from different river sections for given land use practices, heights of dikes, scenarios of their failures or removals, precipitation patterns; while the spatial GIS-based Inundation module maps water released from the river into levels of standing water and thus it estimates the area of the region affected by the flood. The direct economic losses are calculated in a “Vulnerability” module. This module could, in principle, incorporate possible cascading effects, such as floods causing unavailability of lifeline systems and its consequences. Also, it may include loss reduction measures increasing sustainability of the region towards floods, e.g., changes in land-use, flood preparedness measures, etc. Further, the MAAS module, would be able to calculate economic losses and gains for different agents, such as individuals, local governments, mandatory or voluntary catastrophic insurance, central government, investors. Integrated all together, the models result in a framework capable of transforming spatial probabilistic scenarios of rains, dike failures, risk reduction measures and risk spreading schemes into histograms (probability distributions) of gains and losses, underpayments and overpayments of agents. In particular, in its simpler version, by starting from stochastic distributions of discharge rates, it derives histograms of direct losses at a given location or subregion.

A goal of the case study in the Upper Tisza region was to analyze feasibility of alternative flood loss sharing programs including local and central governments, individuals, investors, international markets, etc. One of them appears to take better into account the solidarity principle resulting from the interviews conducted in the region, when losses are partially covered by a mandatory insurance (or a regional catastrophe fund) coupled with direct aid from the government. The contingent credit supplements the insurance. Therefore, the model was directed to the evaluation of the mandatory insurance capacity and the demand for contingent credit.

2.1. Adaptive Monte Carlo Optimization.

The described above integrated catastrophe management model opens up the possibility for "if - then" analyses, which allows the evaluation of a small number of policy alternatives. For example, "if" the government raises the height of the dikes by x meters "then" the insurers can expect loss reduction by y%. Proposed in Section 1 scenarios use fixed assumptions on participation shares, coverage, premiums, etc. Estimating a desirable flood-loss sharing program by testing these assumptions in "if-then" manner would result in a very large number of tries. Consider a simple example. An insurer in the region can have different policies regarding the extent of cover it offers, say 0, 10%, 20%,…, 100%, i.e., 11 alternatives. For 10 locations the number of possible combinations is 10^{11}. With one second per evaluation (to run all modules), the computer time required for the evaluation approaches 100 years. Therefore, with 100 locations the straightforward "if - then" analysis runs into eternity. The same computational complexities arise in dealing with location-specific premiums or investments in different segments of dikes. To avoid these and find a strategy, best, in a sense, against all possible catastrophes we apply an Adaptive Monte Carlo optimization (stochastic) framework. Its fundamental question concerns the evaluation of a desirable policy without the evaluation of all alternative options. For more detail on the application of the Adaptive Monte Carlo optimization model see (Ermolieva 1997, Ermoliev et al., 2000, 2001, Amendola et al., 2000, 2001). The Adaptive Monte Carlo optimization model consists of three interacting blocks: "Feasible Policies", the Monte Carlo "Catastrophe Model", and "Indicators". The block "Feasible Policies" represents all specified decision variables for coping with floods, in this case these are premiums and coverage of the flood-related private insurance. Also, they can include heights of dikes, land use modifications, etc. Varying these variables we, thus, affect and estimate performance indicators such as profits of insurers, underpayments or overpayments by the insured, costs, insolvency and stability.

The essential feature is the feed-back mechanism updating policy variables towards desirable outcomes defined in terms of a goal function maximizing, for example, wealth of the region and profits of the insurance. This mechanism relies on stochastic optimization techniques. Losses are simulated by the catastrophe model, causing an iterative revision of the decision variables after each simulation run. In a sense, the Adaptive Monte Carlo optimization simulates in a remarkably simple and evolutionary manner the learning and adaptation process on the basis of the simulated reversible history of catastrophic events.

2.2. Modelling the decision problem

Stochastic optimization provides a framework for the iterative revision of policy decisions embedded in catastrophe management models. These decisions influence the contribution of location-specific risks to the overall catastrophe losses. The problem was approached in a manner similar to the adopted in (Ermolieva, Ermolieva et al., 1997, Ermoliev et al., 2000, Amendola et al., 2001), in particular, for the earthquake case studies on the basis of previous theoretical developments[2]. Let us outline here only a simplified version of the model. The study region was subdivided into a number of cells $j = 1,2,...,m$. A cell corresponds either to a set of households at a certain site, or a set of zones with a similar land-use structure, or an administrative district, in such a way that a consistent representation of vulnerable goods can be achieved. In this case, the cells consist of the values of the physical structures with an estimate W_j of the property values or "wealth". At time t, catastrophes, which are simulated by the stochastic model, affect at random different cells and produce mutually dependent losses L_j^t. If $x = (x_1, x_2,..., x_n)$ is the vector of the decision variables, say height of a dike, reinforcement measure, then losses L_j^t to a cell j at time t are transformed into $L_j^t(x)$.

The insurance decisions concern premiums paid by individuals and the payments of claims in the case of catastrophe. Let τ be a random (stopping) time to a first catastrophe within a time interval $[0,T]$, where T is a 50 years planning horizon. Let L_j^τ be random losses at location j at time $t = \tau$. Under the present assumptions, the capacity of the catastrophe insurance in the upper Tisza region needs to be evaluated only with respect to financial loss-spreading decisions. Let us use a special notation for their components such as π_j, φ_j, v, q, y. If π_j is the premium rate paid by location j to the mandatory insurance, then the accumulated mutual catastrophe fund at time τ together with the proportional compensation $v\sum_j L_j^\tau$ by the government is equal to $\tau\sum_j \pi_j + \nu\sum_j L_j^\tau - \sum_j \varphi_j L_j^\tau$, where $0 \le \varphi_j \le 1$, is the insurance coverage for cell j. Thus, in this model we assume that the compensation to victims by the government is paid through the mandatory insurance.

The stability of the insurance program depends on whether the accumulated mutual fund together with the governmental compensation is able to cover claims, i.e., on the probability of the event:

$$e_1 = \tau\sum_j \pi_j + \nu\sum_j L_j^\tau - \sum_j \varphi_j L_j^\tau \ge 0 \ . \qquad (3)$$

The stability also depends on the willingness of individuals to accept premiums, i.e., with the probability of overpayments:

$$e_2 = \tau\pi_j - \varphi_j L_j^\tau \ge 0, \ j = 1,...,m . \qquad (4)$$

Apart from the compensation $\nu\sum_j L_j^\tau(x)$ the government arranges a contingent credit y with a fee q to improve the stability of the mandatory insurance by transforming event (3) into (5):

$$e_3 = \tau\sum_j \pi_j + \nu\sum_j L_j^\tau - \sum_j \varphi_j L_j^\tau + y - \tau q y \ge 0 . \qquad (5)$$

Here we assume that the mandatory insurance pays the fee $\tau q y$ and receives the credit y, whereas the government pays back the credit with the interest rate γy, $\gamma > 1$.

The likelihood of events (4)-(5) and values e_2, e_3 determine the stability (resilience) of the program. In a rough way, this can be expressed in terms of the probabilistic constraint

$$P[e_2 > 0, e_3 < 0] \le p , \qquad (6)$$

where p is a desirable probability of the program's default, say a default that occurs only once in 100 years. The main goal can now be formulated as the minimization of expected total losses $F(x) = E\sum_j (1 - \varphi_j) L_j^\tau + \gamma y$ including uncovered (uninsured) losses by the insurance contracts and

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[2] see: Ermolieva et al. 1997, Ermolieva 1997, Ermoliev et al. 2000, Ermoliev et al. 2000a, Ermoliev et al. 2000ab, Ermoliev et al. 2001

the cost of credit γy, subject to the chance constraint (6), where vector x consists of the components π_j, φ_j, y.

Consider a function

$$G(x) = F(x) + \alpha E \max\left\{0, \sum_j \varphi_j L_j^\tau - \nu \sum_j L_j^\tau - \tau \sum_j \pi_j - y + \tau q y\right\} + \beta E \sum_j \max\left\{0, \tau\pi_j - \varphi_j L_j^\tau\right\}, \tag{7}$$

where α, β are positive parameters. It was shown (Ermoliev et al. 2000a) that for large enough α, β a minimization of function $G(x)$ generates solutions x with $F(x)$ approaching the minimum of $F(x)$ subject to (6) for any given level p. This is a key idea for solving the original problem involving highly non-convex and even discontinuous constraints (6) typical for many other risk management problems under extreme uncertainties. Risk measures similar or related to (6) were discussed, for example, in (Artzner et al., 1999) and (Jobst and Zenios, 2001).

3. Numerical Results.

All together, there are 96 flood planes in the Tisza valley, but not for all of them there were sufficient data available for this study. Therefore, the analysis started by a detailed modelling of the Paládcsécse region, which is very well representative for risks of severely affected areas of the Upper Tisza, e.g. floods severity, property values, incomes, and population. This pilot region consists of 11 municipalities, and for each municipality there were data on vulnerability of its built environment and activities. The results concerning losses distributions for the pilot area were scaled up to other two adjacent regions (Szamosközi and Bereg), by factors estimated on the basis of available data on property values, floods severity, and potential losses. This scaling procedure was implemented because data were insufficient to run in its completeness the catastrophe model; it was based on historical data and judgment of Hungarian experts (see references mentioned in above). In this way, it was possible to conduct numerical experiments over 3 interconnected flood planes. The insights gained for these regions are consistent with the objectives of the investigations, i.e. to shape possible (robust) flood loss management program, evaluate it and present to stakeholders in view of designing an overall policy for risk burden share.

In the Tisza basin floods can be provoked both by river water overtopping and breaking of the dikes as well as from rise of ground water or snow melting. The current practise of loss compensation applies only to the later case. These studies are directed towards the analysis of robust combination of insurance institutions covering losses due to dike breaks and induced overtopping. The flood occurrences are modelled according to specified probabilities of flood events (precipitation patterns) and related dike breaks. There are three dikes allocated along the river branch of the pilot area. Table 4 shows the probabilities of their failures conditioned on the severity of the event (flood return period). To obtain representative samples of potential events (losses), 10000 Monte Carlo simulations of the flood management model were performed. Modeling time horizon covers 10 years.

Figure 2 shapes the distribution of losses in the pilot area[3]. For the assumed time horizon, the average loss is about 4.7 Mill HF equivalent to about 17200 USD[4]; in the worst case, losses rise to about 145 Mill HF. In the reference period, by scaling up to the three basins, the losses results in an average ~ 634Mill HF and, in the worst case, ~ 19600 Mill HF.

By numerical experiments, a number of different policy options, based on the stakeholders' interviews, were analysed. These concerned the demand for financial aids, possibly provided through property/fire bundled insurance subsidized on the country level, private flood-related insurance and government. Besides, the need of insurance in "ex-ante" financial measures, such as ex-ante credit or reinsurance, was estimated. Clearly, there may be infinite number of different "if-then" combinations of these options. Therefore, besides

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[3] The numerical experiments use realistic but not official data, therefore, further discussed results have illustrative character.

[4] Exchange rate for year 2001, 1 HF equals 0.0037 USD.

the pure "if-then" analysis of feasible policies motivated by stakeholders, also the "robust optimal" policies were investigated.

Event return period	Dike 1	Dike 2	Dike 3
100	0.12	0.2	0.28
150	0.18	0.22	0.4
1000	0.19	0.33	0.45

Table 4. Dike break probabilities, pilot region (Paládcsécse flood plane).

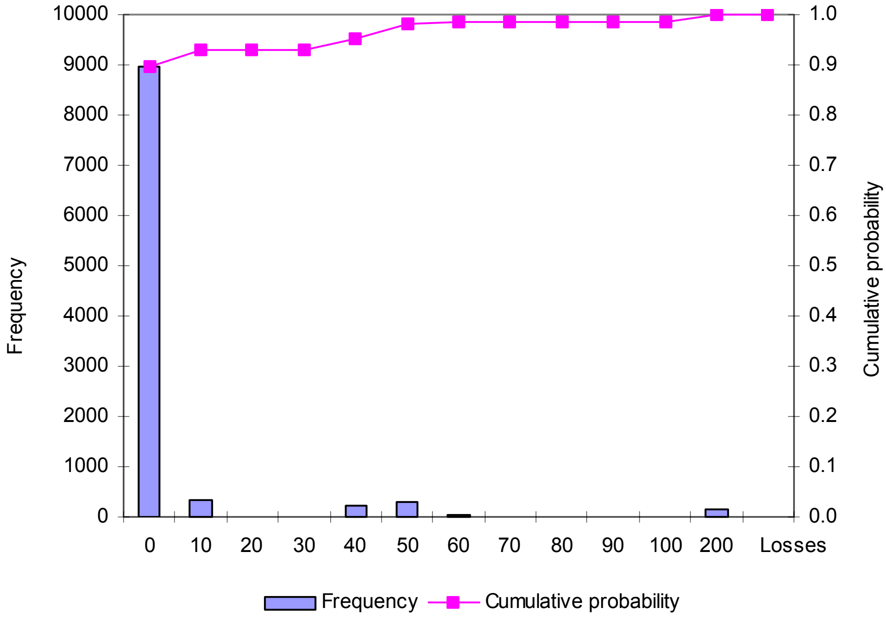

Figure 2. Distribution of catastrophic flood losses: pilot region.

Scenario 1: based on current practice.

Scenario1 was proposed to let stakeholders compare new policies with the financial implications of existing ones. The main idea of the experiments was to stress the necessity of a well-balanced insurance program. Its design solely relies on the comprehensive evaluation of the resilience of the region (structural and financial) to flood losses. It takes into account the regional and the institutional financial constraints, e.g., survival constraints of the program, incomes of individuals, budgets' limitations of local governments, etc.

According to the practice typical for all former socialist countries of Central Europe, the central government, as a rule, was the only institution that provided coverage and relief to flood victims. Quite often this was full compensation of public and private losses. In fact, this practice did not create any incentives for private investments into flood mitigation and response programs. In recent years due to the changes on the political arena and also to the escalating flood losses, the government officials would welcome more private responsibility.

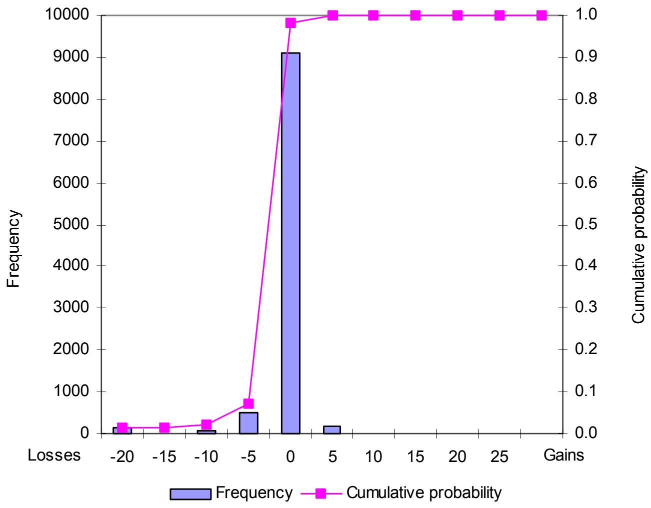

Figure 3. Shortfalls of property insurance.

Thus, current tendency is to decrease state interventions. Depending on the political circumstances and disruption provoked by floods, compensations to flood victims range within 50% and 80% of losses. In addition to this, a voluntary private insurance (bundled with the property/fire line) proposes coverage of 80% flood losses to its participants: in the pilot region, 30% of households have property/fire insurance and, thus, receive flood loss compensation. Monthly premium of an average household to this insurance equals 1300 HF, which is equivalent to 4.5 USD. This corresponds to about 5% of the average monthly income in the region (~ 27500 HF). Insurance claims that 2% of these premiums is for catastrophes other than fire, the main catastrophe being flood. Therefore, the average premium for floods is approximately 8-10 cents USD. This premium goes into a so-called Hungarian catastrophe fund. In this transition period, it is not very clear how these two systems interact or superimpose.

Figure 3 shows the estimated density distribution function of the variable “Shortfalls of property insurance”. It indicates the discrepancy between resources of the property/fire insurance (accumulated in the flood fund through premium payments from the pilot region) and losses which insurance is obliged to cover. On the horizontal axis to the right from zero there are insurance “Gains” (cases when premiums’ payments exceed coverage of losses). To the left from zero there are insurance “Shortfalls” (cases when premiums are insufficient to cover liabilities). According to Figure 3, the resources of the insurance are often lacking (probability of default is 0.07). A column marked “-5”, for example, means that in 487 out of 10000 simulations there is need in additional sum of about 5 Mill HF. Mean shortfall of the insurance equals to approximately 8.6 Mill HF (cumulated over 10 years). Scaled up to the three basins it results in 1162.9 Mill. Shortfalls estimate how much cross-subsidies the insurance needs from the outside regions to compensate for losses in the pilot region.

Figure 4 shows approximate density distribution function of the government exposure to the occurring floods[5] (government is obliged to cover 80% of the losses). The exposure measures financial resources needed by the government and, therefore, the load on taxpayers (region-wide or

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[5] The calculation of exposure for other assumptions (50% or 100%) is straightforward.

country-wide) to aid flood victims. Mean exposure (over 10 years) is 31.3 Mill HF. Scaled up it results in 4225 Mill HF for the three flood planes.

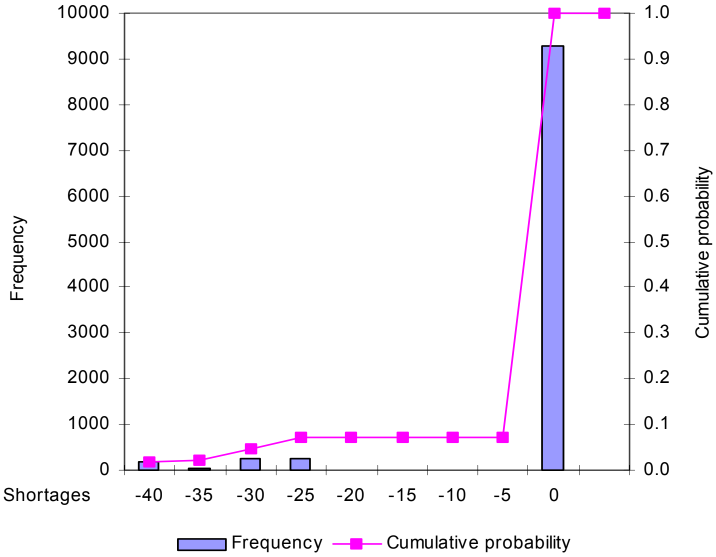

Figure 4. Exposure of the government

Figure 4 applies when the government compensation mechanism and the private property/fire insurance act independently of each other. Such independent, uncoordinated organization may very often result in unjustified overcompensations of losses, which means heavier loads on taxpayers and regional catastrophe funds. This situation may occur, in particular, when private insurance is subject to secrecy and information on its policies is not revealed to the government. The Scenario 1 indicates the need for well-balanced public-private systems such that depicted in Scenario 2.

Scenario 2: reduced government compensations, increased role of private insurance.

In Scenario 2 the role of private insurance systems is much larger. The government exposure, on the contrary, is decreased by lowing government compensation down to 10%. The Scenario involves voluntary private insurance bundled with property/fire line (similarly to Scenario 1, 30% of the households participate in this insurance). The insurance compensation in this Scenario equals 40% of the losses. Correspondingly, monthly premium of an average household is reduced to 650 HF. The property/fire bundled insurance is complemented by private flood risk insurance.

The very low government compensation will encourage households to buy insurance. For the government it will result in largely decreased burden on the taxpayers.

The shortfalls of the property/fire insurance are distributed similarly to Figure 3. They can be overcome by adjustment of premiums.

For the private flood-risk insurance there are two main Options for premiums calculations. Option.1 is the so-called solidarity principle, according to which premiums are based on average losses over all municipalities. In accordance to this principle, the insurance collects 1.92 Mill HF premiums from the pilot region (over 10 years), or approximately 0.175 Mill HF (over 10 years) from each municipality.

Option 2 (risk-based) calculates location-specific premiums according to average loss at each municipality. On this principle municipality Tiszakorod, for example, has to pay 1.675 Mill HF over

10 years. Municipalities Tiszacsecse and Milota add 0.27 and 0.0012 Mill HF of premiums respectively. Other municipalities are practically not risk-exposed: for 9 out of 11 municipalities the solidarity principle would result in significant premiums overpayments (see Table 5).

	Premium (over 10 years)		
	Option.1 (Solidarity)	Option.2 (Risk-based)	Option.1 ('Fair')
Municipality			
Tiszakorod	0.175	1.675	1.62
Tiszacsecse	0.175	0.270	0.24
Milota	0.175	0.001	0.01
The 8 other ones	0.175	0.000	0.01

Table 5. Municipality-specific premiums, private insurer, for the 3 options

Because of low incomes, it may be difficult for some municipalities to pay the risk-based premium. On the other hand, safe locations (not exposed to catastrophes) may not be willing to pay full amount of the solidarity premium or, on the contrary, they may be willing to grant additional financial support to flood victims. Besides, because of multimode distributions[6], average losses are not an appropriate estimate for premiums.

For this case, the stochastic optimisation model outlined in Section 3.3 allows the decision maker to estimate premiums based on the individual constraints of municipalities (such as incomes, willingness to overpay premiums, etc.) as well as the solvency constraint of an insurer. This Option 3 makes the insurance more attractive and it guarantees the risk-insurer required level of solvency (probability of default is set to 0.02).

Thus, the robust "fair" premiums of Option 3 reflect insurers' stability level, financial capability to compensate for catastrophic losses, and, in general, his access to reinsurance and financial markets. These premiums establish certain stochastic equilibrium (in terms of equations (3)-(6)) between insurance demand and supply. By varying the so-called risk factors or "fairness" weights introduced in (7) it is possible to achieve any desirable level of solidarity between regions defined as willingness of safe locations to pay for poor and risky ones. In the case analysed (low solidarity), for locations premiums are shown in Table.5. Average loss (mean shortfall) of the insurance, Figure 5, is 30 Mill HF and average gain is 13.3 Mill HF. Probability of the default is 0.02

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[6] See Figures 7-9. The multimode distributions are due to the fact that a continuous distribution for discharge rate in the river results in discontinuous distributions of flooded areas according to morphology and characteristics of dikes.

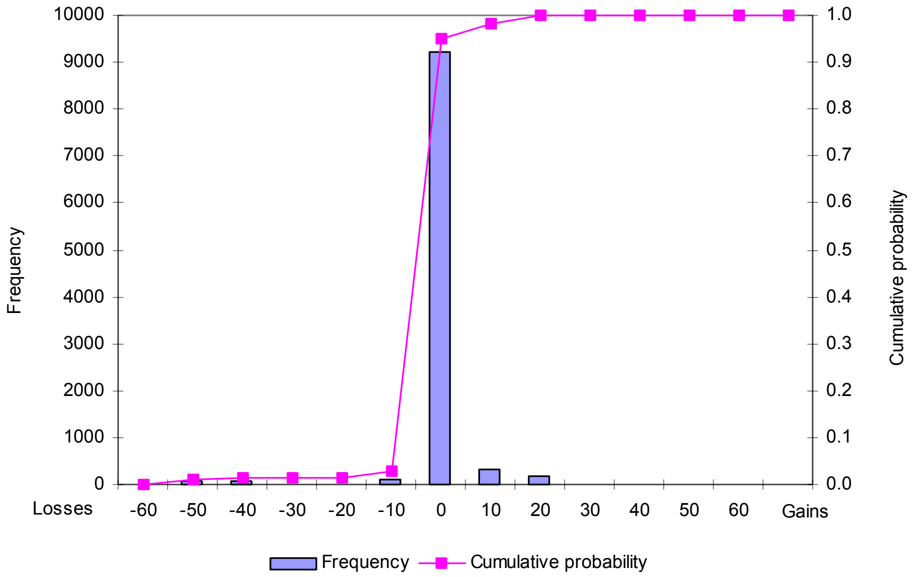

Figure 5. Shortfalls of private risk-insurance, Option 3, “fair” premiums.

Scenario 3: Mandatory all-hazards insurance.

Scenario 3 analyses “efficiency” of a mandatory all-hazards (AH) insurance. The AH insurance may be run by the central government itself.[7] The premiums to the insurance are based on egalitarian principle, Option.1. The AH insurance covers 100% of losses to all flood victims and charges such a premium that it experiences default in 5% of all simulations (probability of default equals 0.05). In this case the premium equals 4.6 Mill HF over 10 years from the whole pilot region or 0.42 Mill HF from each municipality. Scaled up to the three basins, it equals 621 Mill HF over 10 years. Monthly income of 60% population in the region is about 27500 HF, annually - 330000 HF, which is below the standards (according to Hungarian statistical office, income below 33600 HF is defined as unacceptable for survival). Therefore, 60% cannot pay premium. They are aided by the government, at a cost of approximately 2.76 Mill for the pilot region (in 10 yeas) or 372.6 for three basins of additional load to the government. Besides, acting as a reinsurer the government has to be prepared to cover 33.3 Mill HF (on average over 10 years, for 5% of default) or, scaled up to three basins, about 4493 Mill HF. The figure will obviously be higher on the level of the whole Tisza valley. Estimated distribution function of the all-hazards insurance is given in Figure 6.

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[7] Such setting may be more efficient due to the several reasons: the government acts as insurer and reinsurer at the same time; all funds are concentrated in the same hands; the reinsurance agreements are easier to be handled; running costs are lower than of private insurance; necessary amount of reinsurance may be (in an efficient way) provided by ministries diverting money from second-order projects.

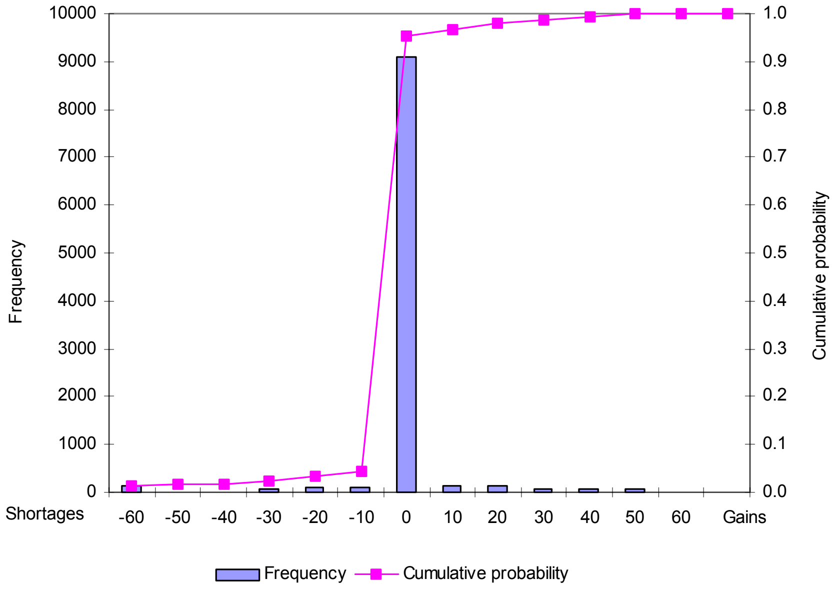

Figure 6. Shortfalls and gains of all-hazards insurance.

4. CONCLUSIONS

The case studies based on comprehensive geographically distributed data sets have demonstrated the ability of the developed methodology to compare different policy options for risk burden sharing, and to model by weighting factors different degrees of solidarity for "fair" and "equitable" solutions.

The methodology is able to incorporate any kind of hazard and vulnerability models, and to deal with dependencies and cascade events. As already included in the Tisza river catastrophe model, the losses are dependent on the reliability of the dikes, and therefore it would be able to study the interplay between mitigation structural measures to mitigate the risks and risk burden sharing. In a similar way, retrofitting of the built environment can be taken into account via the vulnerability models both in the case of earthquakes and floods (e.g. waterproof constructions. But, in this case, even emergency preparedness and response measures could be taken into account, e.g. early warning, which allows reducing the exposure of the goods at risk.). In this way, models and tools can be used as a *mitigation measure* in integrated disaster risk management programs. The case study on the Upper Tisza floods shows how the modeling tools can assist the stakeholders and policy makers to better comprehend the catastrophes, their consequences, and the measures (loss sharing and mitigating programs) in order to deal with catastrophes in a robust way. The model can easily take into account any considerations of fairness suggested by public. On the other hand, it can compare these to the strategies suggested by the model as the optimal in terms of regional welfare maximization.

Aknowledgments

Thanks are due to Aniello Amendola for useful comments and suggestions.

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