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ASSESSMENT OF A FLOOD MANAGEMENT FRAMEWORK

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Abstract

Computer models are increasingly being used in society in order to gain an understanding of complex scientific and social problems. Despite a vast quantity of available modelling schemes, policy evaluation still remains one of the unsolved problems associated with flood management. Simulation models are increasingly employed for this problem as well as forming a basis for decision making. However, these models are often stand-alone and generally lack decision support for the evaluation of management policy strategies. We have, therefore, during recent years been developing a multi-criteria based framework (SEMPAI), particularly designed for flood damage strategy assessment in developing countries. The framework consists of a simulation model, a set of coping strategies, and a decision analytical tool. Needless to say, there are many aspects of such policy strategies that must be taken into consideration. In this paper, we assess some proposed features for evaluating flood management solutions through a qualitative study.

Keywords: Flood management strategies, policy decision making, decision support, multi-criteria decision making

1. Introduction

The resulting impact of disasters on a society depends on the affected country's economic strength prior to the disaster. The larger the disaster and the smaller the economy, the more significant the impact becomes. This is most clearly seen in developing countries, where weak economies subsequently become even weaker. Therefore, the strength and frequency of some countries' experiences with natural disasters place disaster risk as one of the most crucial aspects for consideration with respect to development planning. Bangladesh, Vietnam, and Mozambique are examples of countries where disasters often strike. For instance, a large flood occurred in Bangladesh in 1988 where 53 of the country's 64 districts where inundated and almost half the population of 110 million were directly affected by the flood [ESCAP, 1991]. In Mozambique, floods in 2000 and 2001 left close to two million people homeless [Red Cross, 2002]. There are significantly long recovery periods in developing countries. Thus, post-disaster liabilities cause severe budgetary constraints on already strained economies. It causes, at the least, a temporary halt to the progression of improving standards of living and causes infrastructure projects to slow down, since recovery costs must be dealt with first. Furthermore, increasing debt causes the countries to fall into downward spirals of poverty, in which there are insufficient time to recover between catastrophes and the process is thus repeated.

Consequently, it is important to include disaster preparedness mechanisms into development planning in order to obtain a long-term sustainable effect, thus reducing environmental and human vulnerability to natural hazards. Simply reinstating earlier pre-disaster conditions is often a waste of funds and effort and will probably not significantly reduce the impact of the next possible event. Effective loss prevention may include numerous alternatives or combined strategies, such as the construction of structural measures, land use regulations, and/or the introduction of warning systems, etc. Such deliberate strategies for the sharing of losses from hazardous events may aid a country or a community in efficiently using scarce prevention and mitigation resources, thus being better prepared for the effects of a disaster.

There are several factors that increase the impact of natural disasters in case of a flood and these include dense and increasing population growth. Long-term effects at the micro level are often worse for a developing country than for a developed country and, for instance, the lack of sanitation may cause the spread of diseases such as cholera after a flood. In addition, there may be a significant increase in the spread of malaria caused by large quantities of standing water.

Furthermore, climate change may cause more extreme weather conditions in the future, which may, in turn, increase the frequency and intensity of disasters. Many argue that a global climate change is occurring. Hare [2003] argues that the impact of a one degree Centigrade increase in temperature causes only a rather low risk of changes in the ecosystem. However, in vulnerable ecosystems, this might have an unknown effect. If the temperature increases by two degrees Centigrade or more, the risk increases significantly and may involve the partial collapse of ecosystems and the extinction of species in addition to socio-economic damage. Again, developing countries are among the most sensitive to any such changes. Hunger and water shortages may occur in some locations while in other regions, floods may occur. Consequently, this further underlines the importance of incorporating disaster prevention mechanisms into development planning.

One of the actions stated at the World Summit 2002, to reduce vulnerability and create a sustainable future, is to have: "An integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century." [UN, 2002]

2. The SEMPAI Framework

During recent years, we have developed a framework called SEMPAI (Simulation and Evaluation with Multiple Perspectives and Agents Integrated) whose purpose is to aid decision-makers in their choices with reference to sustainable flood handling strategies, cf. [Hansson et al., 2006; Brouwers et al., 2004]. The framework consists of a flood simulation model, a set of policy parameters, and an evaluation module to assist in policy decisions. In SEMPAI, we support stakeholder analyses with cross-disciplinary data as well as decision making facilities, and the purpose is to illuminate important aspects that should be considered and, additionally, to reveal and handle large degrees of uncertainties in attempts to spread the loss in developing and emerging economies.

Furthermore, we also apply sensitivity analyses using different constant values for different parameters. These include different uncertain variables used in the simulation model, for instance the variable *magnitude*, which provides a value for the strength of a possible flood. For further details on parameters and settings used within the framework consult [Hansson, 2002; Hansson et al., 2007b]. These types of experiments were also performed for other variables such as the *level of compensation* provided by a government to a property owner, who had experienced a flood etc. The results from the different simulations were then compared against each other for abnormal or deviant results. This validation technique also provides the modellers with an overview regarding how the behaviour of a system changes. If deviant results occurred, the model was further investigated and altered accordingly. The procedure was then repeated. In addition, several parameters, procedures, and functions within the simulation model were shown on the screen each time the investigated objects were used within the simulation. This is known as the animation technique, cf. [Luu, 1999], and is employed to track changes within the system for the specific object investigated.

The assessment of the effectiveness of a flood management framework is somewhat difficult, since such a model is supposed to reflect a real-world system and there are no absolute means of verifying the correctness of these types of techniques [Gustafsson et al., 1982]. However, there are methods available to analyse the appropriateness of the models, for instance by performing comparisons of outputs etc. In essence, there are three methods of studying the effectiveness. The *first* method involves assessing the appropriateness of the proposed framework by conducting interviews with experts in the field who are prospective users of such a framework. This is the topic of this paper. The *second* method is to run projects using the framework, and to this end two large case studies using SEMPAI have been conducted, one in Tisza, Hungary [Hansson and Brouwers, 2002; Brouwers et al., 2004] and one in the Red River, Vietnam [Hansson et al., 2006; Hansson et al., 2007a,b]. For the Tisza case, the actual implemented strategies were elicited and validated during a sequence of interviews [Vari, 2000; Vari, 2001; Vari et al., 2003]. The *third* method involves conducting post-case assessments. In the Tisza case, a second stakeholder workshop was conducted in 2002 at which the stakeholders were provided with the opportunity to view the results from different perspectives as well as performing sensitivity analyses using the framework [Ekenberg et al., 2003].

3. Appropriateness Study

In order to assess the appropriateness and the proposed use of the SEMPAI framework, one of the preferable methods is to conduct interviews and have discussions with potential users, i.e. experts and decision-makers who deal with complex environmental decision situations, preferably flood oriented. This method was chosen since it provides an opportunity to extract rich and detailed data. Furthermore, if necessary, uncertainties can be clarified and specific topics can be explored in depth. For this study, several important features, which are important to include in complex environmental policy decision problems, were identified through extensive literature studies [Hansson et al., 2007c] as well from results from earlier workshops and work performed, cf. [Hansson et al., 2007a; Brouwers et al., 2004; Vari et al., 2003]. These features are discussed in conjunction with the respondents' replies in order to assess the appropriateness of these factors which in turn indicate the function of the SEMPAI framework. One criticism towards this type of method is that the researcher could be biased and may inadvertently focus on certain aspects. This was borne in mind when designing the method for this study. The semi-structured approach, combined with pre-fabricated support sheets, was designed to offset such biases.

The first task was to identify the potential respondents. These were selected from institutions and companies working with environmental policy decision making and included the Swedish National Defence College, the Swedish Ministry of the Environment, the Swedish Environmental Institute, the Swedish Environmental Impact centre, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish International Development Cooperation Agency (SIDA), the Swedish Rescue Services Agency, and the Nacka municipal environmental and planning committee. 15 people, made up of nine males and six females, were originally contacted by email or telephone. Eleven of these answered by phone and/or email and a reminder was sent to the remaining four which produced no responses. From the eleven who did answer, four were selected as being of relevance based on their work and the focus of the framework, but from these four only three were willing to participate as the fourth was somewhat preoccupied with a significant natural disaster which had just occurred in Sweden and which required immediate attention.

The remaining three respondents were interviewed in their offices. All sessions were semi-structured and in which the subjects were allowed to talk freely about their work situation and provided the interviewer with an insight regarding how they performed their daily work. Thus, the interviews were conducted in an open and neutral fashion with a written support sheet available for the interviewer only. If issues on the support sheet arose during the interview, the interviewer asked the respondent to elaborate, thus providing their unguided thoughts on these aspects. After the first part of the interview, the SEMPAI framework and its features were presented, and the respondent could freely express opinions and ask questions during and after the presentation.

Respondent 1 is a person whose work involves the presentation of hazard maps for municipalities. For instance, if a municipality is planning the land use for a specific area, a flood hazard map is created as background material in order to highlight risky areas. Respondent 1 is educated in meteorology.

Respondent 2 is a person working as the leader of a team involved in simulation and optimisation models. The output of a model is presented to decision-makers and discussed for further evaluation. Each simulation within this model is carefully prepared and a large quantity of data is entered into the model. The model is then optimised using several parameters and the optimal strategy based on one or several goals is found. Thus, the respondent has a background and experience in modelling and evaluating complex decision situations.

Respondent 3 is a politician in a municipality, working within an environmental and planning committee and who has been very active and has been involved in many development planning situations and decisions.

This selection of respondents thus provided a selection of different usage views for a flood management framework.

4. Study Results

Flood management policy decisions are complicated. The flood modelling itself includes several and various difficulties. Flood hazards are low-probability events that cause correlated damages. This is treated in [Hansson, 2002], and will not be discussed any further in this paper which will, instead, concentrate on policy issues with reference to modelling.

The SEMPAI framework contains simulation and evaluation models which are integrated into the same framework for iterative assessment of different policies. The following set of features further distinguishes it from other attempts in the area:

- Ability to handle short- and long-term modelling in the same model.
- Ability to handle micro and macro levels in the same model.
- Includes several perspectives, not only financial.
- Includes several stakeholders' views and preferences.
- A set of predefined parameters to start a policy simulation and evaluation session.

In the following, there will be a discussion as to how the above features were assessed by the respondents. For an overview of other attempts, see [Hansson et al., 2007a; Mechler, 2003].

4.1. Integrated Simulation and Evaluation Model

Simulating floods creates large quantities of outcome data which must be structured and presented to the stakeholders in a comprehensible way. Hence, in SEMPAI a decision tool is connected to the framework's simulation model. Within the decision tool, data can be evaluated using different methods and presented accordingly. For instance, the flood management strategies that are under evaluation can be presented as tree structures or influence diagrams.

The concept of initially simulating the problem at hand, by using different alternatives, and then, after the simulations, performing sensitivity analyses on the result in a participatory manner was considered highly interesting by all respondents. Respondent 2 expressed the importance of the decision tool and sensitivity analyses as being very important, based on the fact that the results are presented to the decision-makers in an understandable fashion. Respondent 1 stated that the tool would be useful for technical companies and consultants, providing evaluations for complex decisions on behalf of municipalities.

4.2. Predefined Parameters

Many aspects are involved in the design of an appropriate model. For instance, a specific policy strategy consists of a number of policy parameters which can all have different values. Policy parameters include, for instance, level of governmental compensation, size of premiums to the insurers, poverty rate, borrowing, and size of funds for education. An example of a policy strategy could include governmental compensation set to 40 per cent of property losses and a premium size set to 1 per cent of the property value. A specific policy strategy might be advantageous to one stakeholder but disadvantageous to another. It is not obvious that a strategy that maximises an insurer's risk reserve is satisfactory to individual property owners. Furthermore, the government can allocate funds to non-structural measures such as education and the provision of a warning system.

The respondents unanimously agreed that the use of predefined parameters would be important. In addition, if some parameters were not to be used for a specific situation, they could be set to zero but still borne in mind. It is difficult, and sometimes almost impossible, to recall all the important features/variables that must be considered in a complex environmental decision situation. Respondent 2 particularly stressed the importance of predefined parameters as being one of the most crucial aspects for the use of such tools.

4.3. Time Aspects

In flood risk assessment models there is a requirement to analyse possible scenarios from *different time perspectives* because, among other factors, of the large uncertainty involved in flood frequency estimations. Flood probabilities are often low and do not indicate the accumulated risk over more extensive time periods. If a long-term perspective with reference to a specific strategy has to be investigated, the simulation period within a model must be very flexible. For instance, if a government requires to investigate a floodwall construction, long-term effects are not only determined by the number of floods but also by the costs involved in both maintaining the structures and the damage costs for, e.g., erosion. A particular example is in Hanoi, Vietnam, where the government has experienced serious problems with the embankments along the Red River due to rats hollowing out the floodwall [ADRC, 1999]. It is equally important to possess the ability to handle short time periods since this is necessary for a highly dynamic environment as changes in the river system are often immediate and have a direct impact downstream. For instance, precipitation, weather, and river conditions may change quickly and may have a direct impact on the river conditions. Pure hydrological models, such as in flood prediction and forecasting models, handle very short time periods, cf. [NWSRFS, 2006; Noel and Dobur, 2003]. However, this is not appropriate for policy formulation, since the focus is on damage reduction and not on the actual flow.

The respondents all discussed the importance of long-term policy decisions, especially for flood management situations and other environmental decisions. All respondents also referred to the ongoing climate change. Respondent 3, in particular, thought that it was important to be able to view the result from both a long-term and a short-term perspective. In many situations, the short-term financial situation is the most important, while in other situations, this pose a restriction for a specific alternative. For other decisions, the environmental long-term aspects are the most important. Moreover time aspects may have different importance for different stakeholders. Respondent 1 pointed out that the importance of short-term solutions must not be forgotten. As an example, implementing measures such as backpressure valves on sewerage pipes in a specific area may have a direct impact and may considerably reduce damage. Thus, it appears to be preferable that a framework is able to handle both kinds of time scales.

4.4. Micro and Macro Levels

Applying a micro level perspective is particularly interesting for the government if, for instance, either re-naturalisation and/or relocation are to be investigated as mitigation measures. This perspective allows the policy maker to either evaluate a situation using the property only or to also include the property owner(s). The value of the property is itself important information for a possible re-naturalisation strategy where households and land must be expropriated, dykes removed, etc. However, the detailed data required for this type of analysis can often be difficult to obtain, especially for a developing country, and in SEMPAI this is not compulsory information. The framework is fully functional using data on the meso or macro level. Applying the macro perspective, the decision-maker considers a national or an international level for flood mitigation. The meso scale handles the problem on a regional level, for instance at the municipality level or at a river basin level, cf. [Messner and Mayer, 2005]. It is important to provide the opportunity for the decision-makers to perform differently scaled analyses – a micro perspective gives a more precise indication with reference to damage whereas a macro scale can provide a broader view of the evaluation problem.

Respondent 2 discussed the fact that it was not important to include the micro perspective, in the sense that it was felt to be unnecessary to actually view the results for a specific individual. A meso level, however, or accumulated micro level data was, however, felt to be of importance. Respondent 1 also mentioned that it is not important to view the result from a micro perspective, but instead emphasised the importance of granularity at the levels above.

4.5. Interdisciplinary and Multi-Criteria Approaches

An important aspect of flood management systems is how the different system components can adapt to new conditions. Hence, in considering methodologies, social, economic, environmental in addition to the technical dimensions of the measures should be taken into account. A framework should recognize the complex interaction between environmental systems and socio-economic systems in order to support policy and spatial planning in the context of global change and societal advance.

For a framework to be useful, it should include aspects from an entire basin, that is, all relevant aspects that have an influence on the river system. Examples include societal aspects such as planning and development of homes, industries, etc., or the construction of structural measures along the river, and environmental aspects such as soil type, elevation, type of vegetation, climate (precipitation), moisture, temperature, etc. Moreover, the vulnerability of these aspects should be considered, cf. [Patz, 1999]. It is also important to recognise that a river is not restricted to a country's borders. Therefore, it is vital to have an interdisciplinary in addition to a cross-disciplinary approach. If a country upstream decides to construct a dam or embankments, this might have severe effects downstream. For instance, any increased discharges upstream bring more sediment downstream [Wood, 2002]. Thus, a framework should also consider these types of environmental aspects. It should also be possible to perform damage assessment for all relevant policy strategies using an interdisciplinary approach. For instance, a policy strategy could withhold the construction of embankments which requires maintenance. If a flood occurs, the damage might be less than before the existence of the embankment, or could possibly be worse if the embankments burst or overtops. The environment behind the embankment could also change after the introduction of such a measure. Previous wetland might become dry, which could cause severe damage to species nesting or living in these environments. On the other hand, land behind floodwalls could be reclaimed by man.

Many models developed to determine the impact of floods and flood handling strategies focus primarily on the financial aspects and tend to ignore environmental and social impacts, despite the fact that they are often of vital importance. In a traditional basic analysis, a single value measure is used for the consequences of a decision, typically a financial value. However, in real-life cases, there is often more than one valid perspective (aspect) that the decision situation can be viewed from, e.g. financial, environmental, and political. Attempting to incorporate more than one perspective into the decision framework leads to the theory of valuing consequences characterized by multiple objectives whose associated methodologies use value trees, value functions, and a trade-off analysis. A mixture of financial and non-financial criteria can be handled by introducing multi-criteria decision analysis (MCDA), which makes the technique particularly attractive for decisions within the public sector. Thus, the framework includes several types of default criteria (other than the financial criterion), e.g., social/health and environmental.

Taking an interdisciplinary approach to flood hazard simulation models requires the close linkage of many subsystems. For instance, the hydrological system is dependent on the weather system and the financial system depends on the behaviour of the river system, i.e. a flood will have a direct and indirect impact on the economy. A factor which causes the model to be even more complex is the *large degree of uncertainty* inherent in the model. The construction of a flood simulation model relies on the expertise of many scientific disciplines such as hydrology, meteorology, civil engineering, statistics, and actuarial analysis. Thus, the expertise required to construct a simulation model for flood management decision is broader than the traditional actuarial domain. Consequently, there are very large uncertainties in the background information and the dependencies between them. Most models tend to ignore this and consequently the output data becomes less reliable. In a flood policy model, a strong focus should be placed on both the flexibility and robustness of approaches and solutions.

All respondents confirmed that a multi-criteria approach would be useful in order for the decision-maker to be able to grasp the entire problem situation. This was stated not only for flood management issues but for many similar environmental decision situations. A new trend in development planning is reportedly that an interdisciplinary approach is advantageous for a sustainable solution, particularly since the number of natural hazards is increasing. Respondent 1, in particular, showed an interest in including more environmental aspects into the work performed on flood issues for development planning, and in particular mentioned the uptake rate of the soil during the different seasons. There will be substantially greater damage caused by a flood which remains for a long period of time, which will occur in the colder periods of the year when the ground is frozen. Respondent 3 said that in the work currently performed within the field of development planning, they always used a multi-criteria perspective. However, it was difficult to see the relationship between the different systems. Thus, a framework supporting multiple criteria would definitely improve the work situation in many ways.

4.6. Multiple Stakeholders and Different Levels

In order to reach a sustainable balance between the environment and the society and to be able to cope with disasters, particularly for a developing country, it is vital that the stakeholders are involved in the decision making process. Munich Re [2006] and the Kobe report [2005] both emphasise that risk is usually shared among several stakeholders and therefore prevention measures concern all parties. There should, therefore, be a broad participation in the decision making process. Such a policy model must allow for the inclusion of several stakeholders, e.g., individuals, local and central governments, non-governmental organisations (NGOs), insurers, re-insurers, lending institutions, donor organisations, etc. It is important that end-users are included into the model setup to increase their confidence in the modelling process.

According to Munich Re [2006], one important aspect that must be addressed in order to obtain a successful evaluation of possible policy strategies is *zoning,* which is important in flood loss models since it is difficult for the insurance industry to examine risk as an individual exposure. Zoning models can supply a broad spectrum of risk assessments. A model should, consequently, have the ability to handle different geographical areas and land use data specified in sections of various granularity. These can be specified as a grid or vector of different sizes, set by the decision-maker or based on the availability of data. The result can then be examined and presented at a micro level, for instance an individual farm, at the municipality level, or as a result of an entire region.

The respondents all agreed on the importance of including multiple stakeholders in complex decision situations such as the above. Respondent 1 mentioned several important stakeholders that ought to be included in a framework including, for instance, electrical companies and real-estate construction companies. These are important for a society and they are dependent on the outcome especially if the alternatives concern structural solutions.

4.7. Weights on Criteria

Adding a multi-criteria perspective to the framework for analysing flood management strategies could be beneficial in the sense that stakeholders can view the problems and perform impact assessments from different points of view [Hansson et al*.,* 2007b]. Floods cause not only financial problems but also consequences that cannot be measured financially, such as the loss of cultural/historical buildings or the destruction of an environmentally sensitive area. It has been proved to be beneficial to add criteria to a model and combine them with the financial aspect for flood management decision situations. Thus, flood policy generation includes multi-criteria aspects, in addition to multiple stakeholders with different objectives and preferences. Such policy structures are typically modelled by criteria hierarchies and assigned criteria weights. Note that there are two independent sets of weights, namely stakeholder importance weights and perspective (criteria) weights.

Since criteria weights are difficult to handle in precise terms, decision-makers should be able to merely rank the different criteria rather than being forced to make numerical assessments. For instance, financial aspects might, for some policy strategies, be more important than social or environmental aspects. In environmentally sensitive areas the environmental criteria might be the highest ranked higher, etc. Despite incurring a computational complexity, this is still feasible. Yalcin and Akyurek [2004] and Hansson et al., [2007b] weight and rank the criteria in this way. Furthermore, it should be possible to rank the relative importance of various stakeholders. For example, the governmental perspective might be considered the most important since it is fully responsible for the outcome of an implemented policy strategy and, in that sense, represents the broadest population. However, this does not totally preclude the opinions of other stakeholders as they are still considered, but they will be lower ranked, and their relative position will be dependent on the particular circumstances involved. This approach has been evaluated in a stakeholder workshop in Hungary during a case study of the Tisza River, where it was agreed by all participating stakeholder groups that the government's opinion should have the highest ranking [Ekenberg et al., 2003]. Furthermore, each stakeholder's selection can be presented as either a stand-alone or can be aggregated when comparing different policy strategies.

To perform a sensitivity analysis on different criteria was felt to be beneficial by respondent 3 with regard to governmental decision work. To view the result from different angles, in general, was found interesting and respondent 1 stated that this is important in order to bridge the gap between stakeholders. Furthermore, respondent 1 also found it preferable to weight the criteria instead of reducing them to some financial value which has been proved to be difficult. Respondent 2 claimed that risk constraints are important in these types of models since some extreme results that might occur may not be acceptable.

4.8. Weights on Stakeholders

For decision-makers and stakeholders to be able to state their preferences and to also achieve as close to a Pareto optimal solution as possible, a decision analysis module was incorporated into SEMPAI. It has been shown that it is a difficult task for stakeholders to handle their preferences unaided [Danielson and Ekenberg, 2007]. The module is a decision analytic tool which offers the possibility to analyse the decision situation in several ways and enables the impact of risk and uncertainty to be handled in a uniform manner.

There are moral guidelines and principles that ought to be followed in order to better handle hazards [IFI, 2005]. One such important principle is the fair treatment of all affected parties, stakeholders, and future generations. The issue of fairness is discussed in most flood management systems, e.g., DERFA, [2004] where weighted factors are used on social groups, or the RAINS model [2000] where the aim is to achieve a consensus decision if possible. The provision of a framework with the possibility in the decision tool to state the preferences of the stakeholders, provide weights at different levels for both alternatives and consequences is considered to be of great importance.

When analysing possible policies, the relative importance of the stakeholders must be considered and this is further emphasised in scenarios where a zero-sum situation prevails. The result from the simulation model can be evaluated, e.g., by the weighting (aggregated groups) of stakeholders. In some restricted situations, it is sometimes possible to find an optimal solution for one of the parties involved. However, such a solution is problematical for several reasons. One main problem is that it would often be politically impossible to make such an aggregation using a black-box approach, i.e. the stakeholders would not accept the outcome to be an objective solution. This has been clearly shown in several interviews performed in the Tisza basin [Ekenberg et al., 2003]. Furthermore, even if fixed numerical weights could be introduced, there is no objective (or even inter-subjective) way of making proper final assignments. The approach advocated in SEMPAI is, instead, to analyse the situation by taking into account a multitude of weights simultaneously (in the form of weight intervals) and studying how they affect the situation. Possible effects could then be investigated and totally unacceptable policies might be filtered out. By adopting this approach, the results from the simulations are analysed using the decision tool and classes of weighted mean losses are calculated. This analysis incorporates sensitivity analyses of the various costs and probabilities involved.

Another policy evaluation problem is connected to the requirement of precise numerical data. Often, the input data is vague and imprecise, which does not fit models requiring fixed numerical data. Thus, ranking consequences without explicit numerical assessments is a preferable feature for flood assessment. A policy strategy could entail numerous consequences ranging from preferable to undesirable. Comparisons provide the decision-maker with the opportunity to not only rank the consequences but also to state the importance of a desired consequence. In this manner, if several stakeholders rank the consequences for the policy strategies under evaluation, it provides an opportunity to make a fair decision, hence, offers the possibility of achieving a closer proximity to a Pareto optimal solution.

Respondent 1 stated that it would be beneficial to view the result from several stakeholders' perspectives. However, the respondent was sceptical since it was doubted that the decision-maker (in this case the government of a municipality) would be interested in exploring the view of other stakeholders, in particular of individuals. Respondent 2 thought that by offering all interest groups the chance to understand the points of view of the other stakeholders, this would be a beneficial means of performing the analyses. However, in the model employed by the respondent, parameters were ranked (placed in order of preference), after which the model optimises over multiple parameters. Respondent 3 was, as respondent 1, sceptical as to how the government would accept the idea of viewing the results from the perspectives of the property owners.

5. Conclusion

A sustainable society able to co-exist with floods must be aware of risks and effects associated with them. The society should diminish the risks by reducing the damage caused by floods; this also includes maintaining the environmental stability in the eco-system. Adequate methodologies and tools are important in order to measure how a specific policy meets the objectives established by the various stakeholders in order to identify conflicting views that may occur, but also to evaluate different strategies in striving for a sustainable solution. Flood management decisions are complicated; they often include multiple criteria as well as multiple stakeholders with different objectives and preferences. The SEMPAI framework integrating several features was developed over a number of years for this purpose. In this paper, its features have been assessed by respondents who are experts in the field of environmental decision making. The features assessed were: having simulation and evaluation integrated into the same framework; a set of simulation features (predefined parameters, micro and macro levels, and short and long time horizons); and a set of evaluation features (multiple perspectives and stakeholders). Of these, most were found to be useful by all respondents. The exceptions were the ability to handle both micro and macro levels within the same model, which was not considered important at the micro level by two respondents and the inclusion of several stakeholders' views and preferences. This latter was not considered important to be important by two of the respondents as it was felt that government would not have sufficient regard for an individual's point of view. However, as it was possible to deal with these exceptions, the main conclusion is that the framework, as an integrated model, was found to be valuable and useful by the expert panel interviewed.

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