Combining integrated river modelling and agent based social simulation for river management; The case study of the Grensmaas project

P. Valkering[1], J. Krywkow[1,2], J. Rotmans[1] & A. van der Veen[1,2]
[1] International Centre for Integrative Studies (ICIS), University of Maastricht, P.O. Box 616, 6200 MD Maastricht, The Netherlands; p.valkering@icis.unimaas.nl
[2] School of Civil Engineering, Department of Integrated Assessment, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Abstract
In this paper we present a coupled Integrated River Model – Agent Based Social Simulation model (IRM-ABSS) for river management. The models represent the case of the ongoing river engineering project "Grensmaas". In the ABSS model stakeholders are represented as computer agents negotiating a river management strategy. Their negotiating behaviour is derived from the so-called Theory of Reasoned Action. The Integrated River Model represents stakeholder knowledge by describing possible long-term impacts of river management options such as broadening, floodplain lowering, and dike building. The computer agents are allowed to specify values for a set of 'uncertain parameters' in the IRM for representing subjective stakeholder knowledge. We show how the coupled model framework can aid to assess the robustness of river management strategies, both with respect to environmental uncertainty and societal support.

Introduction
River management is a typical example of a complex problem involving a variety of stakeholder interests and fundamental environmental uncertainties. The Dutch government aims to take the different interests and views explicitly into account by allowing stakeholders to participate in the planning process. The aim of our research is to analyse stakeholder influence on the decision-making process, and its possible consequences for the river system, using Integrated Assessment modelling and Agent Based Social Simulation.

Methods
There are numerous mutually comparable theories of individual and collective stakeholder behaviour, stemming from the fields of social and individual psychology, economics, and artificial intelligence. In this paper we apply the so-called Theory of Reasoned Action (Ajzen & Fishbein, 1980). According to this theory the individual's intention to perform a behaviour is determined by its attitude (personal desire) towards performing the behaviour and a subjective norm, see Fig. 1.

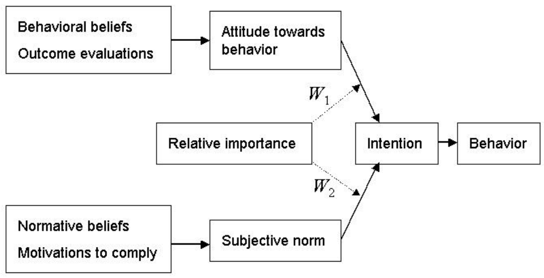

Figure 1. Relations among beliefs, attitude, subjective norm, intention, and behaviour according to the Theory of Reasoned Action (After Ajzen & Fishbein, 1980).

The Integrated River Model concept is depicted in Fig. 2. The model concept is implemented in computer code as a cross-section model of the Meuse at Borgharen. The modules are based on basic principles of river engineering (Jansen, 1994), groundwater dynamics (Strack, 1989), nature development (Maaswerken, 1998), etc.

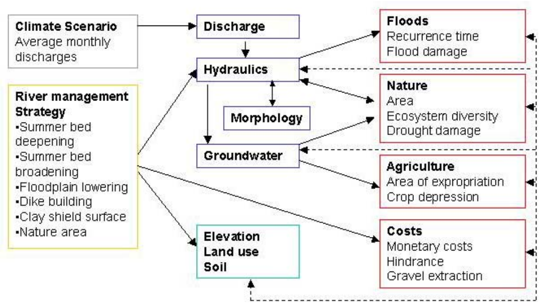

Figure 2. The concept of the Integrated River Model.

The concept of model coupling can be described as follows (Krywkow, 2002). The 'behavioural beliefs' of agents (see Fig. 1) are represented as their 'perspectives on uncertainty': value settings for uncertain IRM parameters related to climate change, hydraulic roughness, morphological developments, and costs and benefits. The agents feed these settings into the IRM to

Strategy variables / Stakeholders	Citizen	Gravel extr.	Policymaker	Nature org.	Farmer
Summer bed deepening (m)	0	4	0	0	0
Summer bed broadening (m)	250	125	250	250	0
Length of floodplain lowering (m)	0	250	500	500	0
Dike building (m)	1	0	1	0	0
Clay shield surface (m)	0	2	0	0	0
Nature area (m)	250	0	750	750	0

Table 1. Egocentric strategies for the salient stakeholders of the Grensmaas project. The strategy variables apply to a river cross-section.

calculate values for a number of decision-making criteria for a given river management strategy. These values form the basis of their outcome evaluation of the river management strategy.

Results

As a first step towards model experiments we have determined 'egocentric' river engineering strategies for the salient stakeholders of the Grensmaas project, see Table 1.
The egocentric strategy of an agent is obtained by maximizing over its attitude, given its perspective on uncertainty, while neglecting subjective norms. Obviously, no one of the egocentric strategies receives broad societal support (see Fig. 3), the strategy of the policy maker being still the most accepted option.

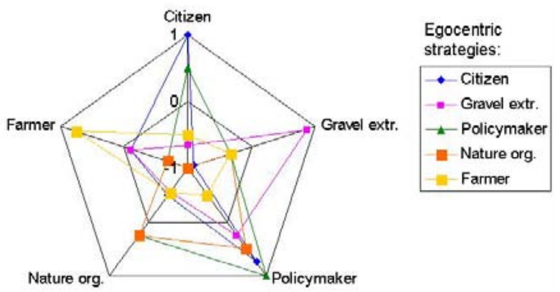

Figure 3. Stakeholder attitude towards the different egocentric strategies. A value of 1 indicates a highly favourable position towards the strategy, 0 indicates a neutral position, and –1 indicates a highly unfavourable position.

In particular, the positions of the nature organization and gravel extractor deviate. Their disagreement, however, does not result from conflicting goals, but rather from a difference in uncertainty perspective. This is represented clearly by Fig. 4, which shows a huge difference in the estimations of costs and benefits of river engineering measures between the gravel extractors and the other parties involved.

Conclusion

We have shown an 'egocentric' model of stakeholder behaviour coupled to a schematic river model. This methodology seems promising to assess robustness and societal support of a broad range of river management options and reveals underlying motives for stakeholder disagreement. Furthermore, the method may be used to elicit stakeholder goals and perspectives on uncertainty, and enhance communication. Further developments will include participatory model use, and the development of more advanced models of collective action and negotiation to assess plausible outcomes of operational river management.

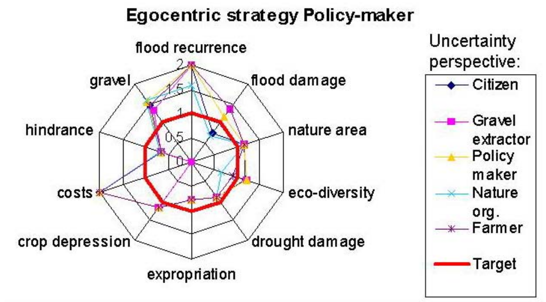

Figure 4. Decision-making criteria for the egocentric strategy of the nature organization according to different perspectives on uncertainty. The values are scaled with respect to a target value.

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