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D6.6.2 BOKU

QR models and documentation for learning about sustainable development, focusing on basic ecological and socio-economic features for an integrative and sustainable development of the riverine landscape of the Kamp valley

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Revision [0]

Abstract

This document presents the final version of the qualitative simulation models related to the sustainable development of the Kamp valley to be used by stakeholders and students as learning material about sustainable development. The models mainly explore aspects related to two topics:

(1) development and implementation of sustainable actions in a river catchment (stakeholder integration, quality of sustainability plans, development of ecological integrity and human well being, probability of catastrophic events) and

(2) hydropower production (water storage and release, water abstraction) and its effect on fish.

The document ends with a discussion about how the material can be used in educational contexts and the follow up of the present work.

Document history

Version	Status	Date	Author
1	Draft, initial version.	19.07.07	Andreas Zitek, Susanne Muhar, Sabine Preis, Stefan Schmutz
2	Final version	31.10.07	Andreas Zitek, Susanne Muhar, Sabine Preis, Stefan Schmutz, Bert Bredeweg, Paulo Salles

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Content

1 INTRODUCTION

This document describes two implemented qualitative simulation models about the Austrian River Kamp case study for the NaturNet-Redime Project. This case study mainly focuses on the development and implementation of sustainability plans on a catchment level and their effect on human well being and ecological integrity, and the effect of water abstraction and storage for hydropower production on fish. The models provide learning material for the NaturNet-Redime QR sub-portal related to ecosystem, social, economic and cultural processes and integrated management and restoration of rivers on a catchment level.

In the Kamp valley catastrophic floods and inundations in August 2002, a nearly 2000-annual event, set new conditions for life and economy facing flood control management, landscape architecture and land use planning with essential and future challenges. The high water event represented a chance to develop the riverine landscape together with the local population as well as with the concerned scientific disciplines considering social, economic and ecological claims with regard to the EU-Water Framework Directive (WFD). The EU-WFD now represents the overriding framework for sustainable river management of surface water resources. Within this framework is the development of a programme of measures which are targeted to rehabilitate the impact of current and historical activities which have degraded the ecology of waters across Europe (URL 1). The main focus of the WFD is the management of river basins, the natural geographic and hydrologic unit. One of the key objectives of the WFD is to achieve the “good ecological status” of running waters by 2015. Fish are one out of four organism groups (fish, macrozoobenthos, algae, macrophytes) that can be used as an indicator to describe the ecological status of running waters; the EU-WFD targets at the restoration of suitable conditions for the type specific community and especially the disturbance sensitive species.

Hydropower production is one of the most important pressures on the river system and on fish in the valley. The use of hydropower has a long tradition in the valley and an analysis of the historical evolution of the run-of-river power stations showed that most sites have existed for several centuries and that only the initial use of the mills had changed. On account of this evolution and by the establishment of the artificial lakes used for hydropower production the character of the river has been substantially changed.

The three reservoir power stations existing at upper section of the project area were built in the sixties and are responsible for a constant discharge regime without small and medium flood events and for the change of the natural temperature regime of the river due to hypolimnetic releases of water. About 16 running power stations lie in the central to lower investigation area, and some of the power plants situated at the valley abstract water from the river for hydropower production and cause significant problems to fish by the creation of residual flow stretches.

On this basis an overall integrated concept towards the sustainable development of the River Kamp landscape has been developed at the University of Natural Resources and Applied Life Sciences, Vienna. Besides the consideration of the spatial scale (from catchment level up to planning onto municipalities) the interdisciplinary work of the different disciplines biology/nature conservation, landscape planning, water resources management, regional planning, agriculture and forestry and hydropower production is of central relevance for the project (URL 2). Moreover, planning is conducted in participation with authorities, stakeholders and the local population. The integration of the population into the planning activities exceeds pure information policy with the possibility for the local population to actively participate in developing the future scenarios for their valley.

Accordingly following objectives were set for the modelling effort:

(1) to develop models to represent the complex task of an integrative, policy driven, stakeholder and science based sustainable catchment management and
(2) to create models that represent the effect of the two different hydropower production modes in the valley (water storage in reservoirs and hypolimnetic releases, water abstraction) on fish as a basis for the development of restoration plans according to the EU-WFD.

To address this problems two models with several sub-models were developed. During the implementation of the models we tried to follow as much as possible the textual description in deliverable D6.6.1 (Zitek, 2006) and the guidelines set by Bredeweg et al. (2005). However, during the implementation of the models the concepts became clearer and to keep the simulations at a manageable size, new features were included in to the models and some of the initial ideas were left aside.

Although some of the initial ideas were left aside, the implemented models are much better able to represent the relevant processes of integrated catchment management and the different effects of the two ways of hydropower production active in the Kamp valley on fish.

2 Model A – "Sustainability management"

2.1 Entities, configurations and quantities

The entity hierarchy for model A "Sustainable management" is presented in Fig. 1. The main entities involved are *Planners* and *Stakeholders* as biological entities (here we tried to capture the idea of the hierarchical structure of biological systems), the *Community*, which lives in the valley (can be seen as a set of entities – e.g. all people living there together with stakeholders), *Education*, *Government* and *Science* as expression of the culture of a country, the *Development plan* as a basis for the implementation of sustainability issues and the *River basin* (the *Kamp valley*) as the relevant environment.

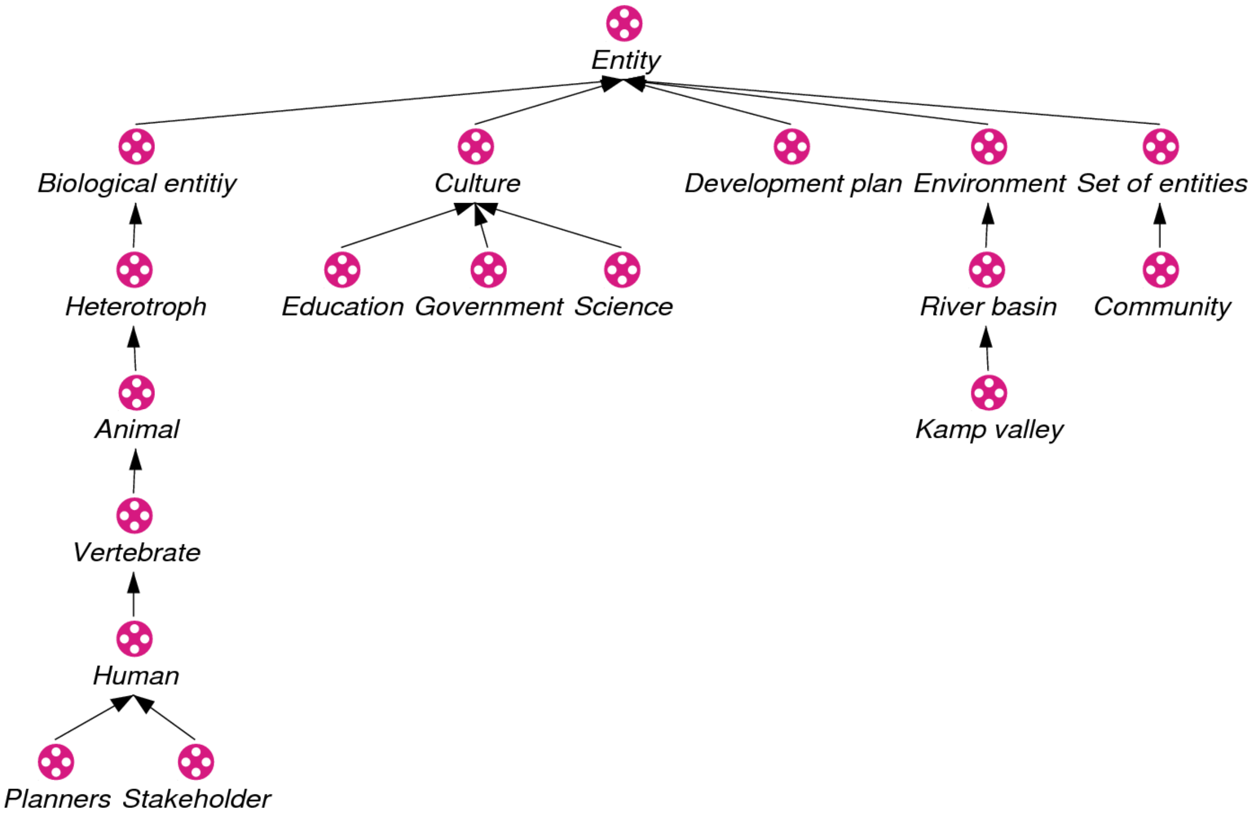


Figure 1: Entity hierarchy for model A describing sustainability processes on a catchment level.

2.2 Configurations

The entities are related by *configurations* defining the basic system structure and describing mainly the direction and type of influences. In the following the configurations of five sub-models are presented (Figs. 2-5).

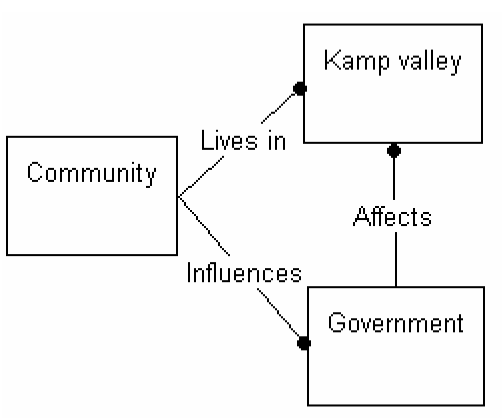


Figure 2: Entities and configurations used to define the system structure of the "Community fear caused by a catastrophic event influences government action for SD" sub-model.

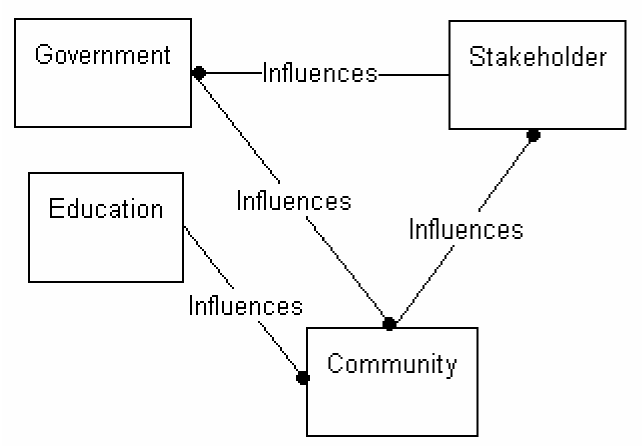


Figure 3: Entities and configurations used to define the system structure of the "Stakeholder participation" sub-model.

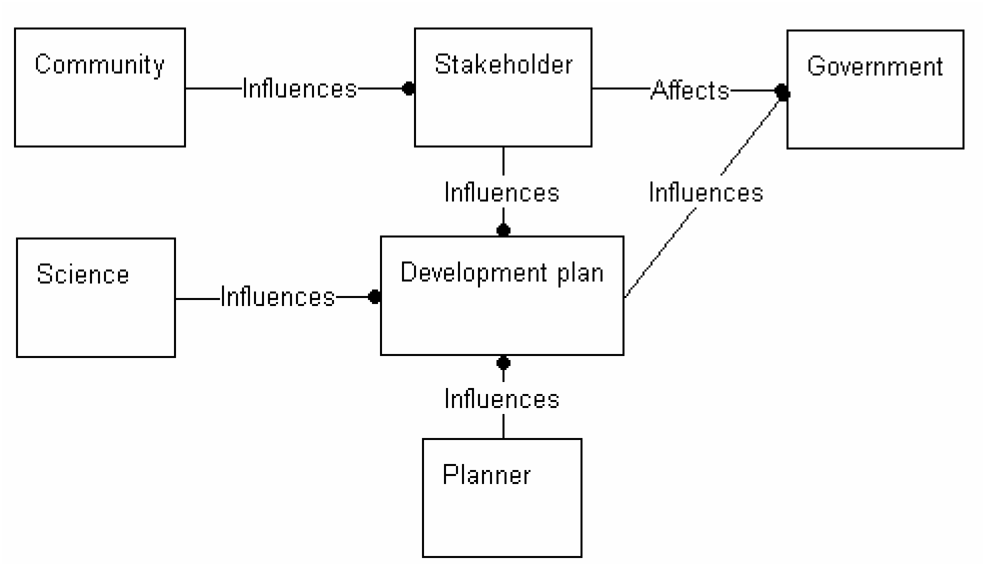


Figure 4: Entities and configurations used to define the system structure of the "Development and implementation of sustainability development plans" sub-model.

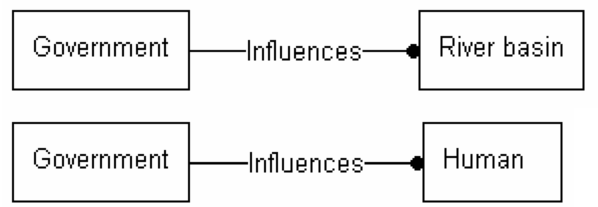


Figure 5: Entities and configurations used to define the system structure of the "Government influences ecological integrity of river basin and human well being" sub-model.

2.3 Quantities and Quantity spaces

The quantities used in the Kamp valley “Sustainable management” model (model A) and their respective sets of possible qualitative values (the quantity spaces) are presented in the following tables. Rates are treated separately from other quantities and remarks are given to further describe the quantities. The quantity spaces are identified by labels that read as follows: mzp = { minus, zero, plus}; zlmh = {zero, low, medium, high} and zlmhm = {zero, low, medium, high, maximum}.

Table 1: Quantities and quantity spaces used in the “Community fear” sub-model.

Quantity	Quantity space	Remarks
	Rates of processes	
Gv action rate for sd as response to fear	mzp	Rate of the government influencing sustainability actions in the valley.
Changing the magnitude of catastrophic effects rate	mzp	Rate of changing the catastrophic effects, is calculated in abstract terms from the balance of sustainable and non-sustainable actions.
	Other quantities	
Sustainable actions	zlmhm	Refers to sustainable actions that are encouraged by the government.
Non sustainable actions	zlmhm	Refers to non sustainable actions that are encouraged by the government.
Magnitude of catastrophic effects	zlmh	Refers to the effect of catastrophic events; non-sustainable actions are seen to increase the magnitude of catastrophic effects.
Fear	zlmh	Refers to the fear of the population after catastrophic events, which as one of the main factors causing political action in the Kamp valley.

Table 2: Quantities and quantity spaces used in the “Stakeholder participation” sub-model.

Quantity	Quantity space	Remarks
	Rates of processes	
Decentralization rate	mzp	Refers to the political concept of sharing governance and giving possibilities of participation to the public.
Intensity of participation rate	mzp	Rate of public involvement in the development process; is influenced by social development, accessibility to the decision making process and public information.
Education	mzp	Rate of change in social development, influencing the capacity of people to participate in political processes.
	Other quantities	
Number of projects with public participation	zlmh	Number of projects implemented allowing for a public participation, driven by the political concept of decentralization.
Number of ways to inform and integrate the public	zlmh	Number of structures for informing and integrating the public; driven by the political concept of decentralization.
Social development	zlmh	Social development forms the basis of active stakeholder participation.
Public information level	zlmh	Refers to information that is necessary for the public to participate in planning processes.
Accessibility to the decision making process	zlmh	Refers to the possibilities for the public to participate in the decision making process.
Stakeholder participation	zlmh	Refers to the level of stakeholder participation; influenced by the intensity of participation rate.
Resources for community driven sd actions	zlmh	Refers to resources that are spent based on integration of community interests.
Resources for not community driven sd actions	zlmh	Refers to resources that are spent not based on integration of community interests.
Investment for a community driven development	zlmh	The resources that are spent for a community driven development based on stakeholder participation.

Table 3: Quantities and quantity spaces used in the "Sustainability development plan" sub-model.

Quantity	Quantity space	Remarks
Rates of processes		
Qualification rate	mzp	Rate of preparing civil servants for acting in favor of sustainability.
Scientific involvement rate	mzp	Rate of scientific contributions to process understanding and technological solutions.
Intensity of participation rate	mzp	Rate of public involvement in the development process; is influenced by social development, accessibility to the decision making process and public information.
Government action rate for sd	mzp	Rate of the government influencing sustainability actions in the valley; is influenced by quality of sustainability plans, group pressure, and resistance against measures.
Private interest build up rate	mzp	Rate that determines the pressure of private interest groups on the government action rate for sd actions.
Other quantities		
Stakeholder participation	zlmh	Refers to the level of stakeholder participation; influenced by the intensity of participation rate.
Process understanding and technological solutions	zlmh	Refers to the integration of various different scientific disciplines into the planning process.
Planners preparedness	zlmh	Refers to the ability of planners to develop sustainability plans.
Quality of sustainability plan	zlmh	Refers to the quality of sustainability plans defined by stakeholder participation, process understanding/technical solutions and planners preparedness.
Resistance against measures	zlmh	Refers to the resistance of the community against measures in situations with insufficient stakeholder participation.
Group pressure	zlmh	Refers to the pressure of private interest groups on the government action rate for sd actions.

Table 4: Quantities and quantity spaces used in the "Government influences river basin and human well being" sub-model.

Quantity	Quantity space	Remarks
Rates of processes		
Government action rate for sd	mzp	Rate of the government influencing sustainability actions in the valley; is influenced by quality of sustainability plans, group pressure, and resistance against measures.
Ecological integrity development rate	mzp	Rate that contributes the ecological integrity; it is calculated in abstract terms from the balance between sustainable and non-sustainable actions.
Human well being development rate	mzp	Rate that contributes the human well being; it is calculated in abstract terms from the balance between positive and negative factors.
Other quantities		
Sustainable actions	zlmhm	Refers to sustainable actions that are encouraged by the government.
Non sustainable actions	zlmhm	Refers to non sustainable actions that are encouraged by the government.
Ecological integrity	zlmhm	Refers to the overall ecological integrity of the river basin influenced by the ecological integrity development rate.
Number of positive factors	zlmhm	Refers to all positive influences on human well being (health, culture, education, safety, clean environment).
Number of negative factors	zlmhm	Refers to all negative influences on human ell being (unhappiness, loss of culture, feeling frightened, destroyed environment).
Human well being	zlmhm	Feeling of being healthy, happy, comfortable, having satisfied basic needs (education, housing, safety, spiritual environmental and economical aspects).

2.4 Sub-model “Community fear caused by a catastrophic event influences government action for SD”

The sub-model “Community fear caused by a catastrophic event influences government action for SD” (CF-SD) shows how the *Magnitude of catastrophic effects* is influenced by *Non-sustainable actions* in the *Kamp valley*. When the *Magnitude of catastrophic effects* is <High>, the *Fear* of the community from future catastrophic events is also <High>; this influences the government to force an increase *Sustainable actions* and a decrease *Non-sustainable actions* as a reaction.

2.4.1 Model fragments

The CF-SD sub-model consists of one model fragment that captures the basic process, which triggers the government to become active in the Kamp valley reducing *Non-sustainable actions* and increasing *Sustainable actions* (Fig. 6). Using this model, one should be able to explore *how non-sustainable actions might cause catastrophic effects, which then become a factor that causes the government to react, because the community lives in fear from future catastrophic events and creates pressure on the government.*

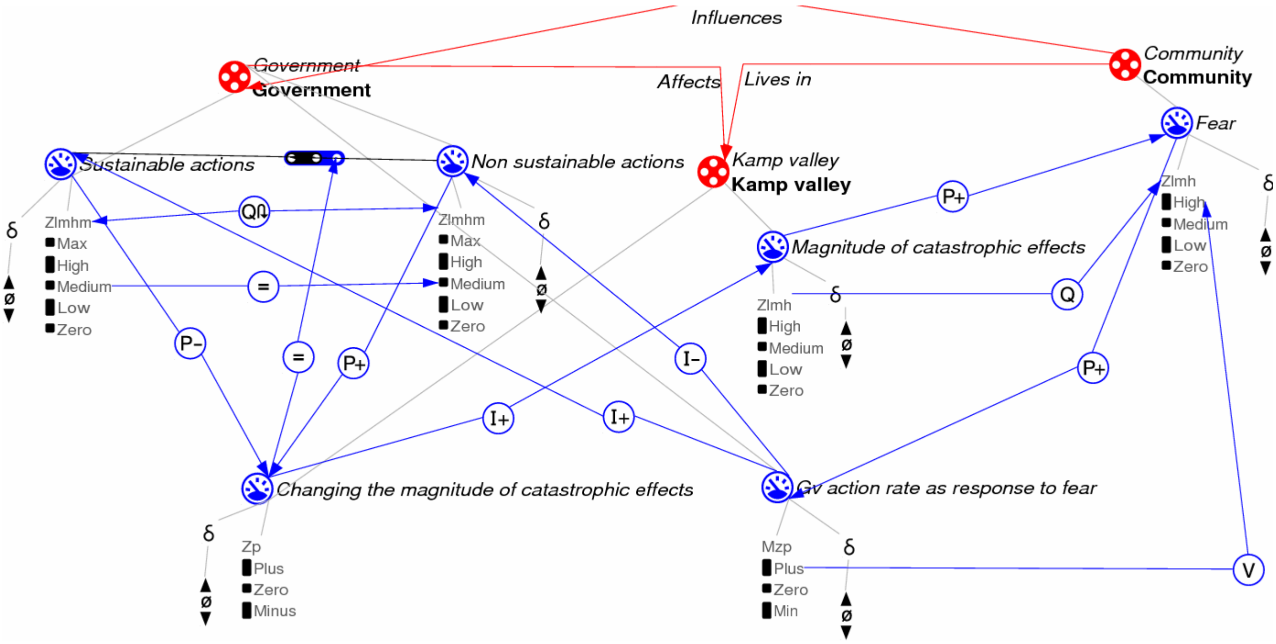


Figure 6: Model fragment “Community fear caused by a catastrophic event influences government action for SD”.

2.4.2 Simulation

Currently this sub-model has one scenario describing a system with *Non-sustainable actions* at its <Maximum> where the *Magnitude of catastrophic effects* is at <Low> at the beginning (not visible at the moment!), but will be triggered via the *Changing the magnitude of catastrophic effect* that is calculated from the relationship between *Sustainable* and *Non-sustainable actions* (Fig. 7); when the *Magnitude of catastrophic effects* reaches its value <High> *Fear* is also set to <High> (related via a directed correspondence); when *Fear* reaches its value <High>, the *Government action rate* as *response to fear* is set to <Plus>, starting to decrease *Non sustainable actions* and to increase *Sustainable actions*. The simulation produces 27 states and no end state, because the model shows a cyclic behaviour (Tab. 5 and Fig. 8).

Fig. 9 shows the value history of all quantities throughout the simulation and Fig. 10 shows a detailed representation of the causal model in state 1.

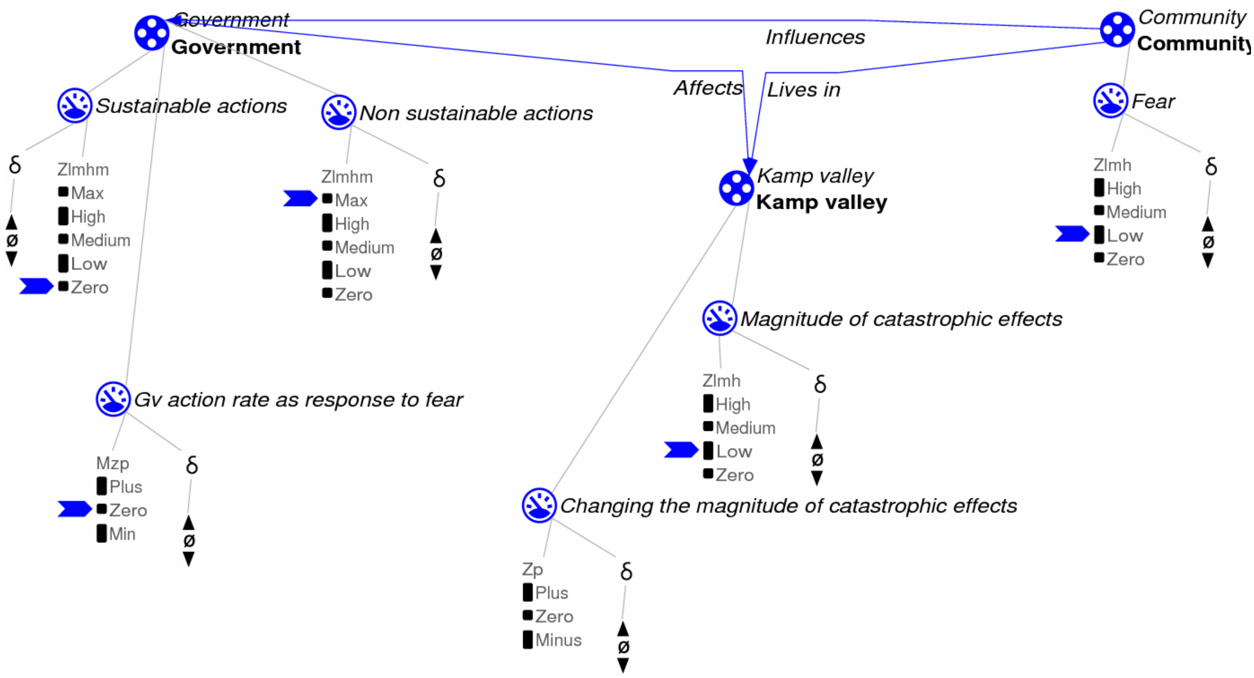


Figure 7: Only scenario for the sub-model "Community fear caused by a catastrophic event influences government action for SD".

Table 5: Simulation summary "Community fear caused by a catastrophic event influences government action for SD".

Scenario name	"Community fear influences gv action for sd"
Full simulation	27
Initial states	1
End states	No – cyclic behaviour
Relevant behaviour path	[1, 2, 3, 4, 5, 6, 8, 13, 16, 22, 1] (Fig. 8)
Behaviour description	Due to the negative rate *Changing the magnitude of catastrophic effects* the *Magnitude of catastrophic effects* reaches <High>, which sets the *Fear* also to <High> setting the *Government action rate for sd* to <Plus>, why *Non-sustainable actions* start to decrease. This causes also the *Magnitude of catastrophic effects* to decrease – the *Fear* of the *Community* also decreases and in our simulation this brings back *Non sustainable actions* to the valley, which starts the process again (Fig. 9).

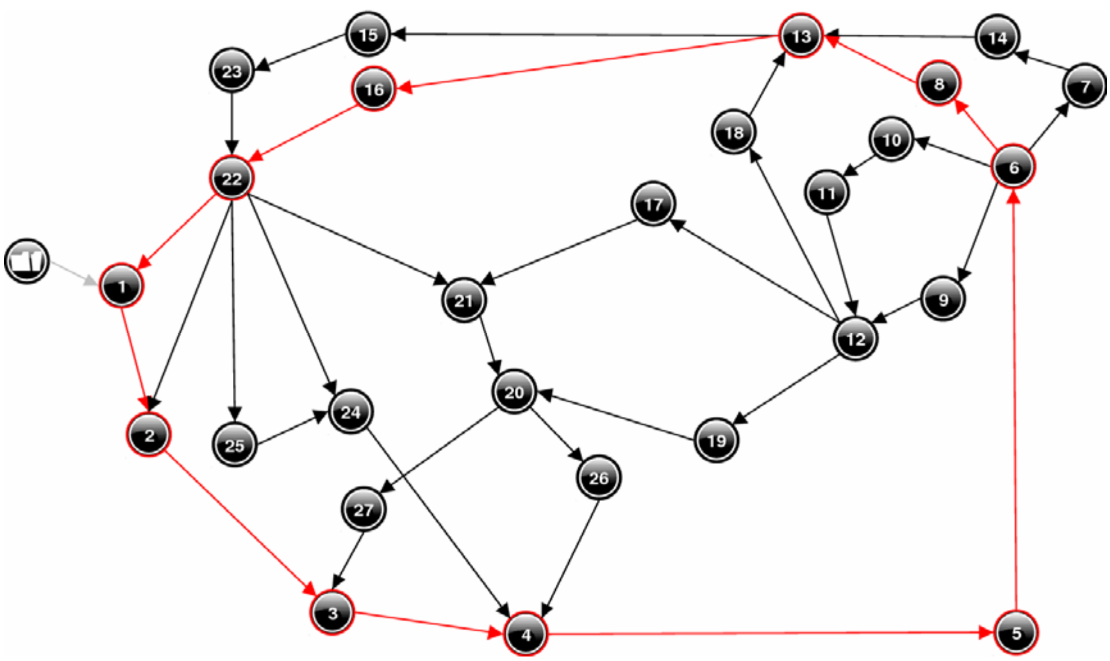


Figure 8: Behaviour graph obtained in a simulation of the sub-model "Community fear caused by a catastrophic event influences government action for SD".

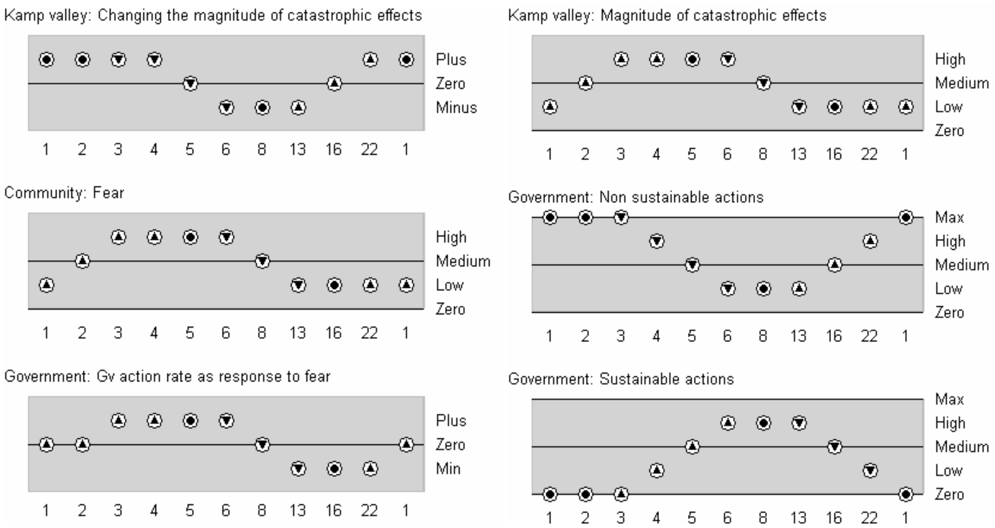


Figure 9: Value history diagrams of the quantities in the described behaviour path of the simulation of the sub-model “Community fear caused by a catastrophic event influences government action for SD”.

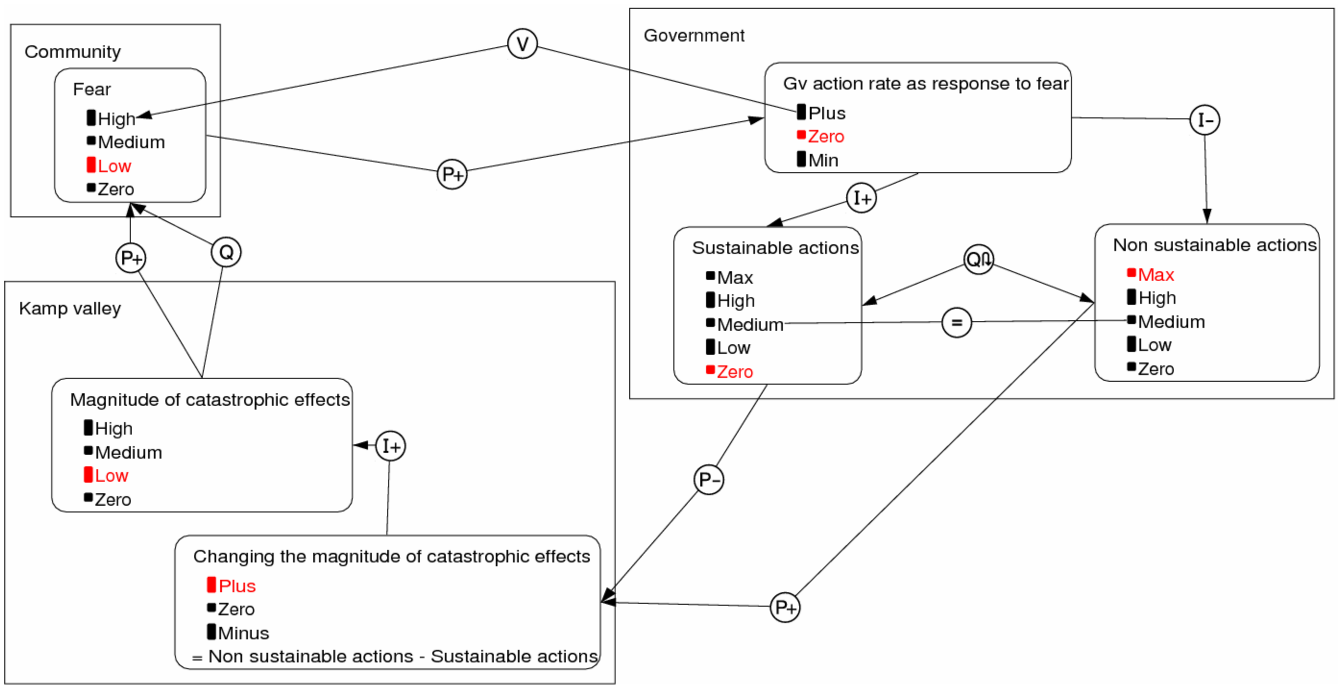


Figure 10: Detailed representation of the causal model in state 1 of the simulation of the sub-model “Community fear caused by a catastrophic event influences government action for SD”.

2.5 Sub-model “Stakeholder participation”

The sub-model “Stakeholder participation” (SP) explores, under which circumstances successful stakeholder participation can take place. *Stakeholder participation* is triggered via the *Intensity of participation rate*, that is defined by different value combinations of *Social development*, *Public information level* and *Accessibility to the decision making process*. The first scenario ends up with the *Stakeholder participation* as the main quantity being simulated, the second scenario simulates the *Amount of money*, that is spent by the government for *Community driven development* – which itself is a result of *Stakeholder participation*.

Using the simulations supported by this model it should be possible to answer the following questions: *what are the circumstances for successful stakeholder participation and under which circumstances, the government spends money for community driven sustainable development.*

2.5.1 Model fragments

The SP sub-model consists of 12 model fragments, eight being static and four being processes. These model fragments are presented below.

2.5.1.1 “Decentralization configuration”

Basic features of the government describing the decentralization process and being highly relevant for the stakeholder participation are summarized in the static model fragment “Decentralization configuration”. It introduces the entity *Government* and the three quantities: *Decentralization rate, Number of ways to inform and integrate the public and Number of projects with public participation.* All of them are set conditional; they only appear in the scenario when explicitly introduced (Fig. 11).

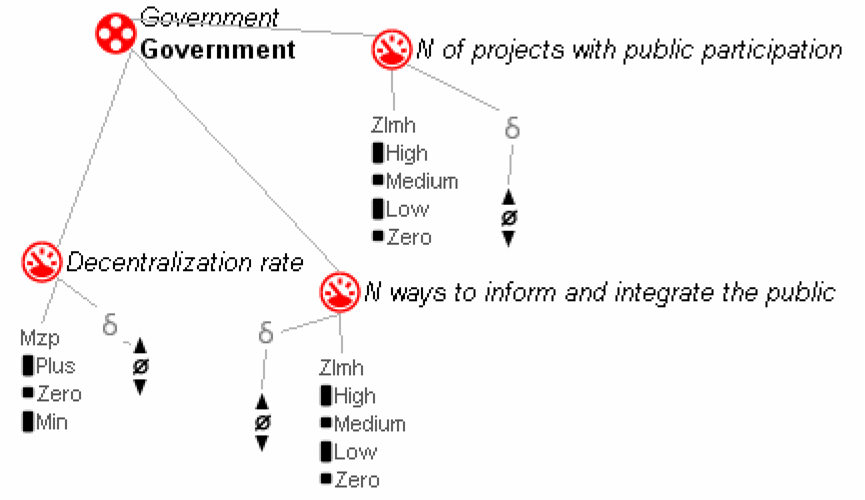


Figure 11: Static model fragment “Government configuration”.

2.5.1.2 “Assume n ways to inform and n projects corresponding”

This model fragment introduces a directed correspondence between the two quantities influenced by the *Decentralization rate* to reduce simulation states as the assumption “Assume ways of info and n projects corresponding” (Fig. 12).

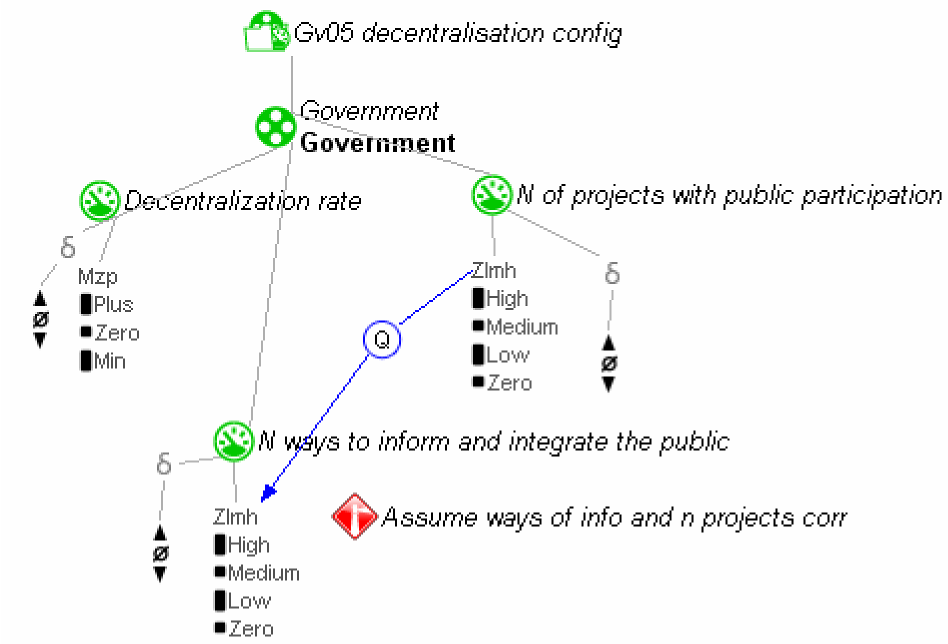


Figure 12: Static model fragment “Assume n ways to inform and n projects corresponding”.

2.5.1.3 "Public participation configuration"

This static MF represents the basic configuration of the community related quantities *Public information level, Social development , Accessibility to he decision making process* (all set conditional) and the *Intensity of participation rate (*set as consequence); these are important quantities to describe the stakeholder participation process (Fig. 13).

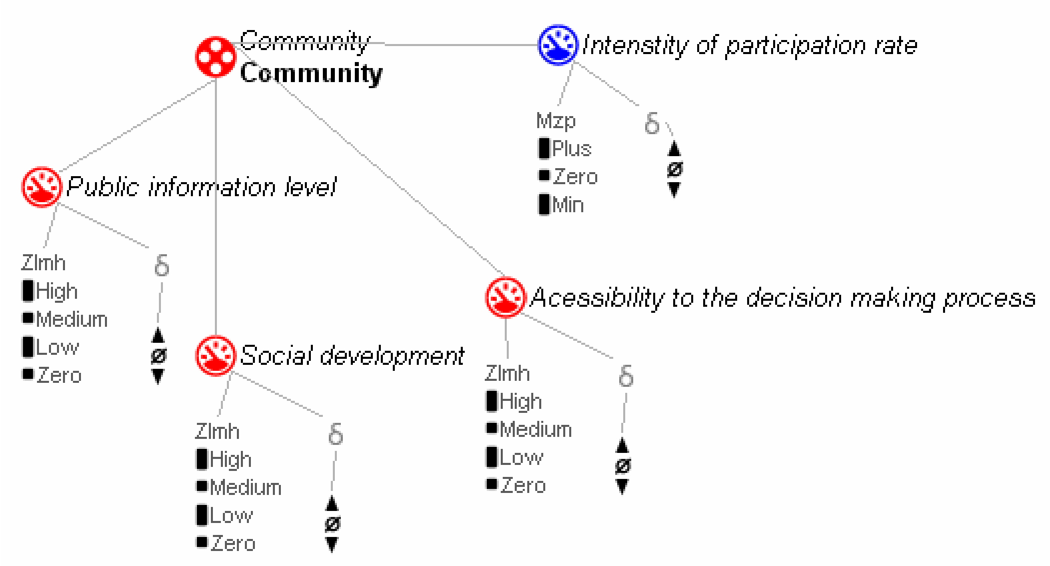


Figure 13: Static model fragment "Public participation configuration".

2.5.1.4 "Assume public participation and accessibility corresponding"

This static model fragment introduces the assumption that the *Public information level* and *Accessibility to the decision making process* are corresponding by using the assumption "Assume public information and accessibility corresponding" (Fig. 14).

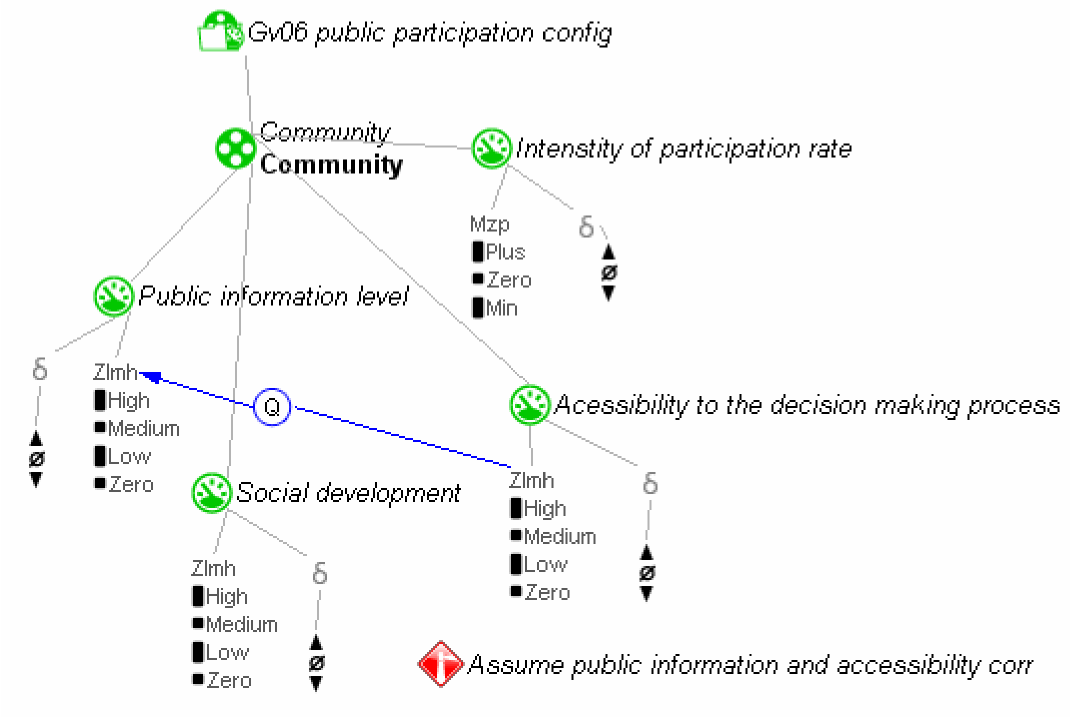


Figure 14: Static model fragment "Assume public participation and accessibility corresponding".

2.5.1.5 "Community involvement"

This static MF shows how the government influences the community and how community related features influence the *Intensity of participation rate* (Fig 15). To reduce the size of the simulation, directed correspondences are set between *Number of projects with public participation* and *Accessibility to the decision making process* and between *Number of ways to inform and integrate the public* and *Public information level.*

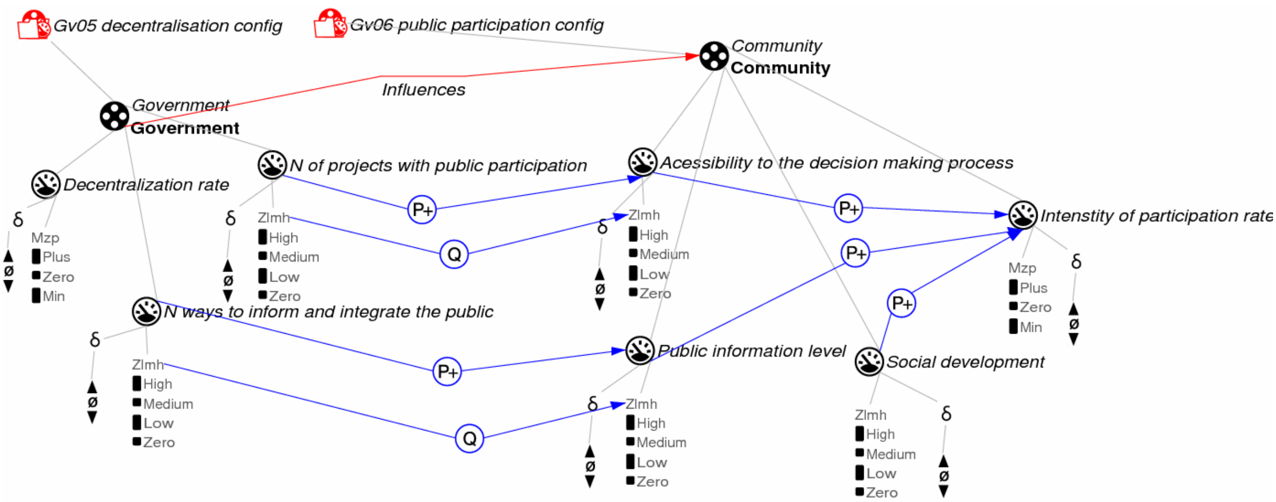


Figure 15: Static model fragment "Community involvement".

2.5.1.6 "Community involvement and social development low"

This static model fragment is the first one of a large amount of model fragments, where the different value combinations for *Public information level* and *Accessibility to the decision making process* and *Social development* are pre-defined with a specific influence on the *Intensity of participation rate* (Tab. 6). Here we start our definitions setting *Social development* to <Low> (Fig. 16).

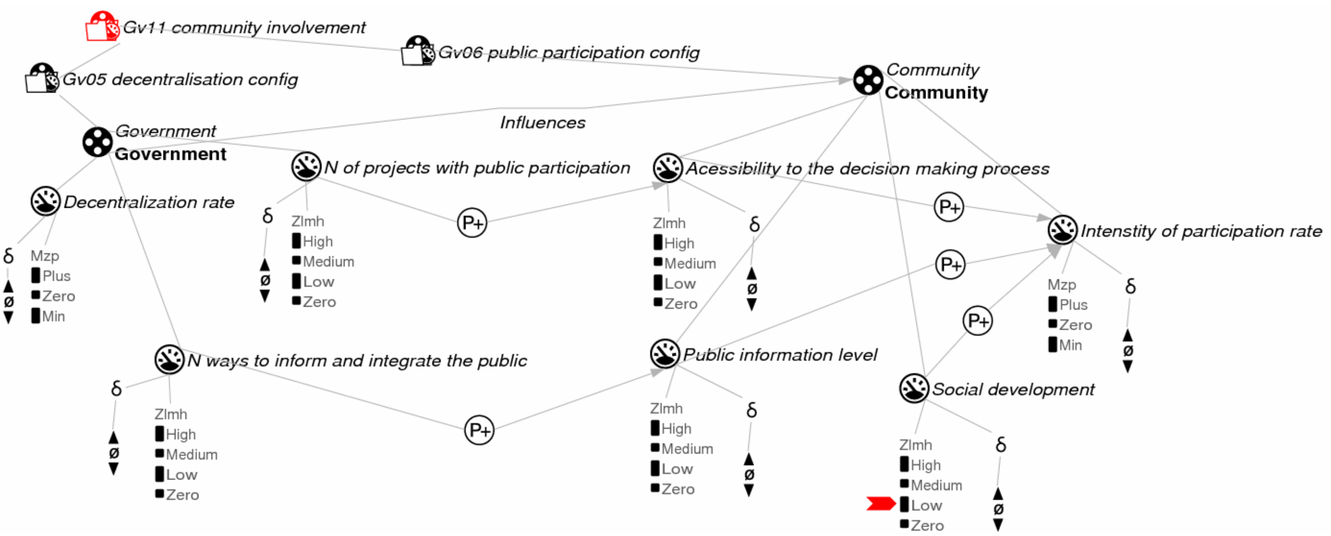


Figure 16: Static model fragment "Community involvement social development low".

2.5.1.7 “Community involvement, social development low and public information low”

In this static model fragment based on 2.5.1.7 additionally to set *Social development* to <Low>, the *Public information level* is also set to <Low > (Fig. 17).

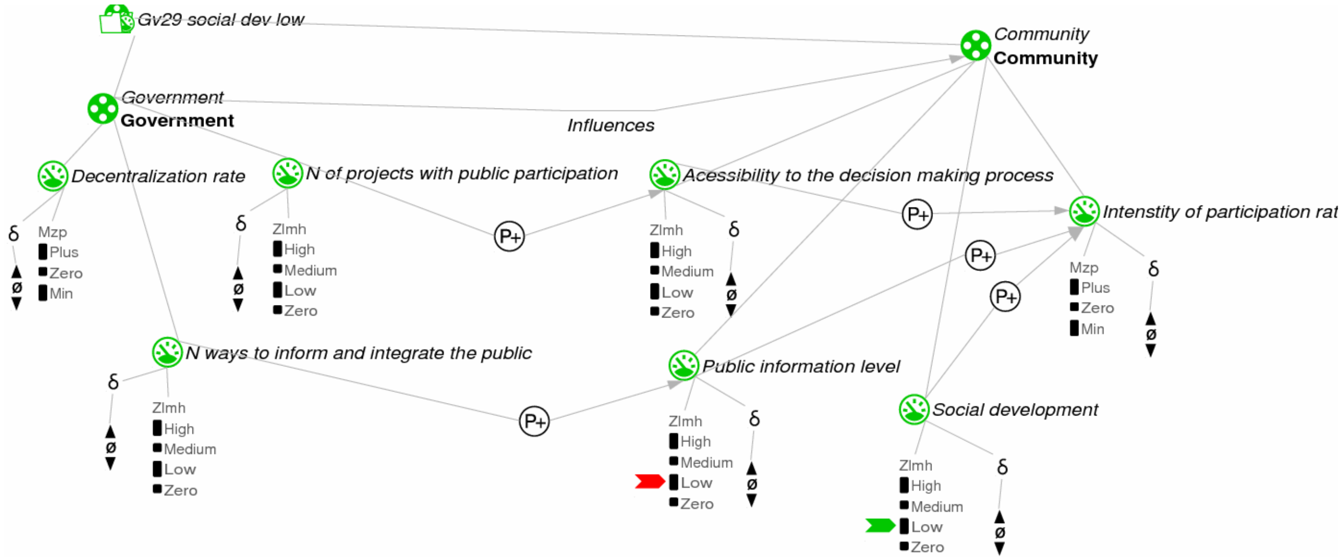


Figure 17: Static model fragment “Community involvement social development low, public information low”.

2.5.1.8 “Community involvement, social development low and public information low”

Finally in model fragment based on 2.5.1.8 additionally to setting *Social development and* the *Public information level* to <Low>, *the Accessibility to the decision making process* is set to <Equal greater zero> which yields an *Intensity of participation rate* of <Minus> (Fig. 18).

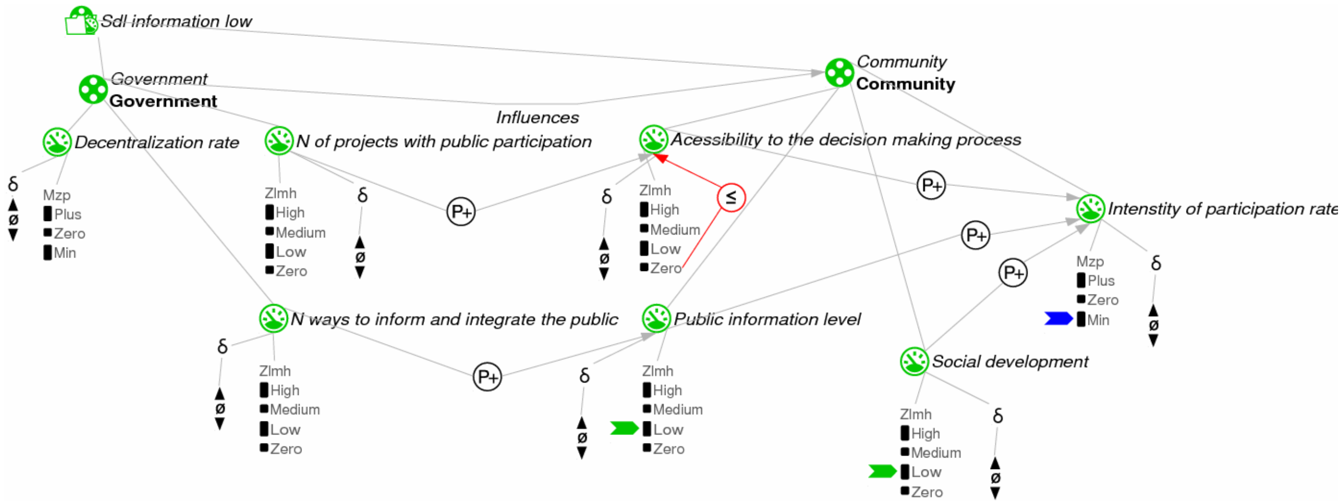


Figure 18: Static model fragment “Community involvement social development low, public information low, accessibility greater equal zero – intensity of participation rate minus”.

2.5.1.9 “Social development process”

This process MF describes *Social development* as an effect of *Education,* which itself positively influences the quality of *Education* (Fig. 19).

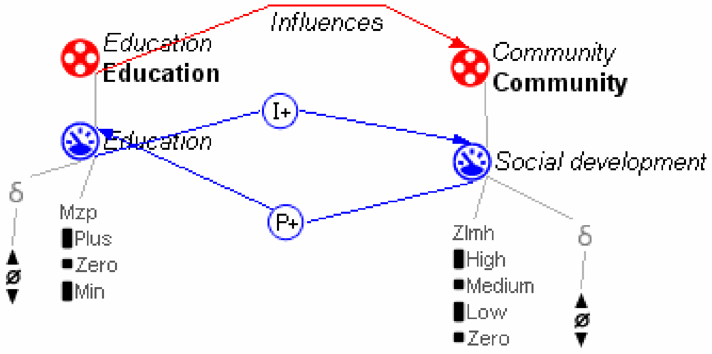


Figure 19: Process model fragment “Social development process”.

2.5.1.10 “Decentralisation process”

This process MF describes the decentralisation process via increasing the *Number of ways to inform and integrate the public* (Internet; TV, newspapers, information events) and the *Number of projects with public participation* as a basis for policy driven community involvement (Fig. 20).

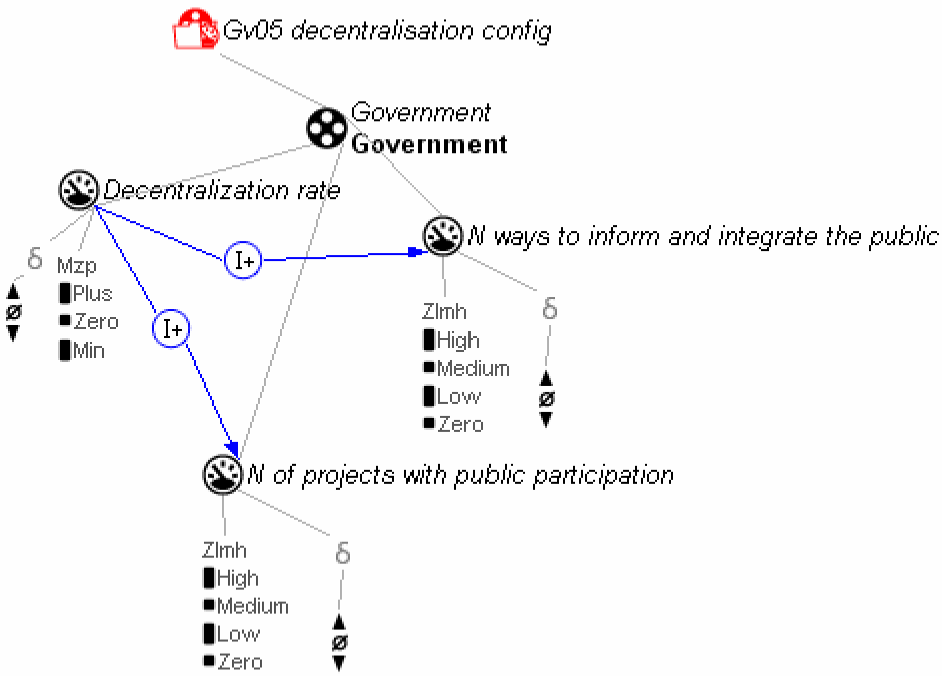
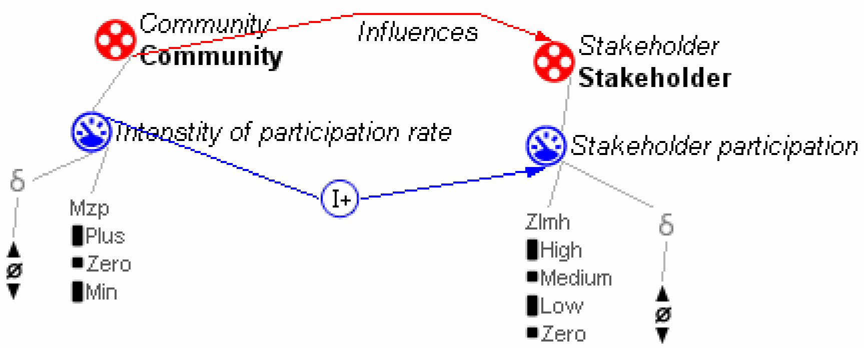


Figure 20: Process model fragment “Decentralisation process”.

2.5.1.11 “Stakeholder participation process”

This process MF describes the effects of the *Intensity of participation rate* on *Stakeholder participation* (Fig. 21).

Figure 21: Process model fragment “Stakeholder participation process”.



2.5.1.12 “Resources for community driven development

This static MF describes how the *Investment for a community driven development* is triggered by the *Stakeholder participation* and then contributes to *Resources for non sd actions* and *Resources for sd actions* (Fig. 22). This MF expresses the idea, that *Stakeholder participation* is the only way to assure that resources are really spent to reach community defined targets. To reduce the size of the simulation, there is a directed correspondence between *Stakeholder participation* and *Investment for a community driven development*.

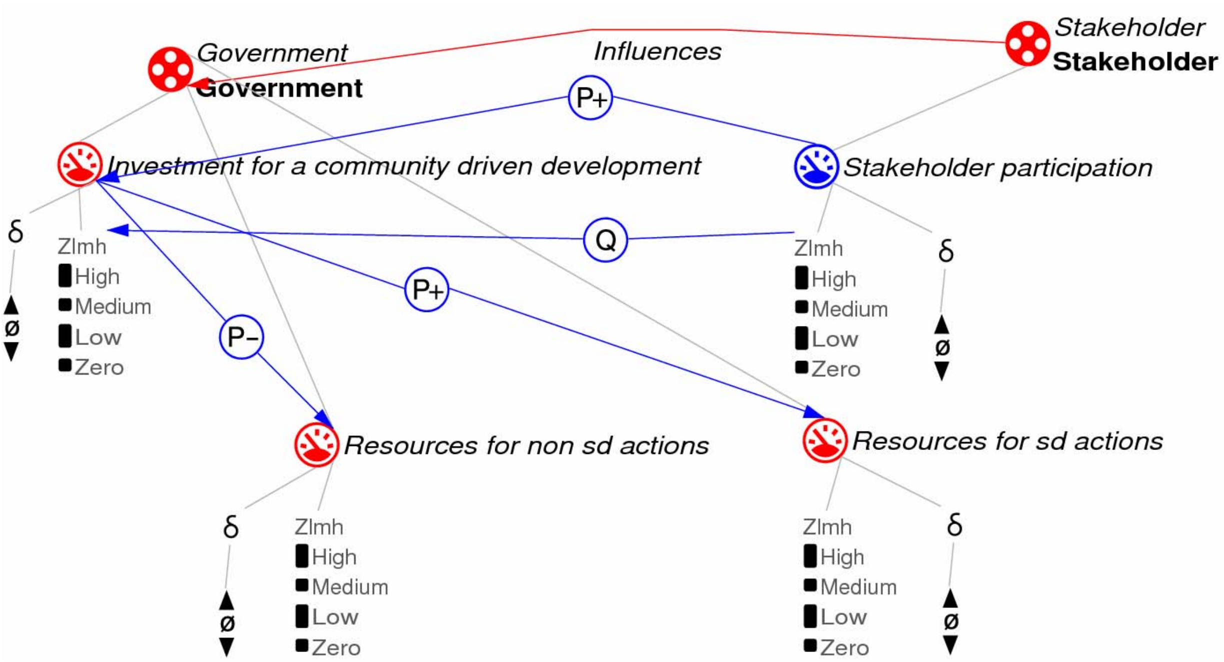


Figure 22: Process model fragment “Resources for community driven development”.

Table 6: All possible value combinations of the quantities Social *development, Public information level, Accessibility to the decision making process* that compose the *Intensity of participation rate*; these potential value combinations have been defined by expert judgement and were implemented in single static model fragments; the value combination shown in Figs. 16-18 are shown in yellow.

Social development	Public information level	Accessibility to the decision	Intensity of part. rate
h	**h**	**h**	**plus**
h	**h**	**m**	**plus**
h	h	l	z
h	h	z	minus
h	**m**	**h**	**plus**
h	**m**	**m**	**plus**
h	m	l	minus
h	m	z	minus
h	l	h	z
h	l	m	z
h	l	l	minus
h	l	z	minus
h	z	h	z
h	z	m	minus
h	z	l	minus
h	z	z	minus
m	**h**	**h**	**plus**
m	**h**	**m**	**plus**
m	h	l	minus
m	h	z	minus
m	**m**	**h**	**plus**
m	**m**	**m**	**plus**
m	m	l	minus
m	m	z	minus
m	l	h	minus
m	l	m	minus
m	l	l	minus
m	l	z	minus
m	z	h	minus
m	z	m	minus
m	z	l	minus
m	z	z	minus
l	h	h	z
l	h	m	z
l	h	l	minus
l	h	z	minus
l	m	h	z
l	m	m	minus
l	m	l	minus
l	m	z	minus
l	l	h	minus
l	l	m	minus
l	l	l	minus
l	l	z	minus
l	z	h	minus
l	z	m	minus
l	z	l	minus
l	z	z	minus
z	h	h	z
z	h	m	z
z	h	l	minus
z	h	z	minus
z	m	h	minus
z	m	m	minus
z	m	l	minus
z	m	z	minus
z	l	h	minus
z	l	m	minus
z	l	l	minus
z	l	z	minus
z	z	h	minus
z	z	m	minus
z	z	l	minus
z	z	z	minus

2.5.2 Scenarios and simulations

Currently the SP sub-model has two scenarios. The first ends with the *Intensity of participation rate* being modelled influencing *Stakeholder participation* (Fig. 23); in the second scenario the quantities describing the *Resources spent for community driven development* are added (Fig. 27). Figs. 24-26 represent the behaviour graph, the value history and the causal model oft state one of the "Stakeholder participation" scenario.

2.5.2.1 Scenario "Stakeholder participation"

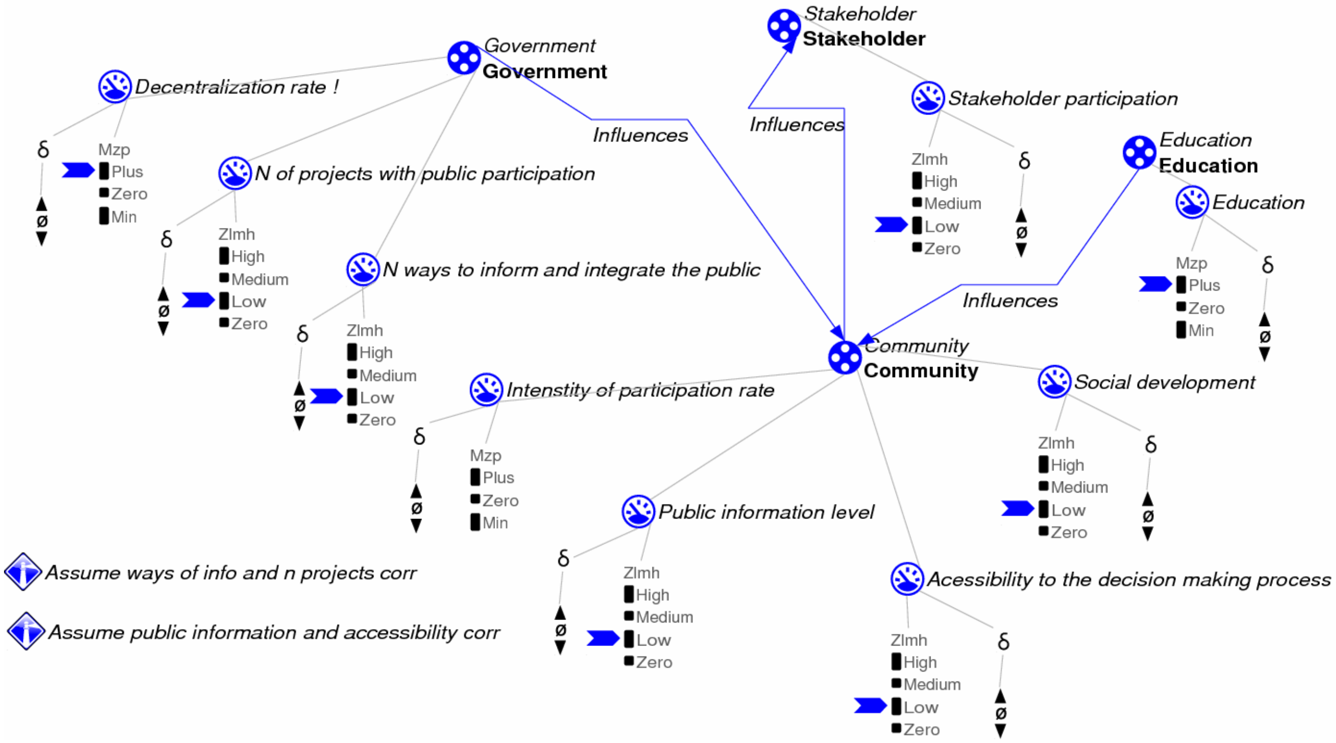


Figure 23: Initial scenario "Stakeholder participation".

Table 7: Simulation summary "Stakeholder participation".

Scenario name	"What affects stakeholder participation"
Full simulation	12 states
Initial states	[1]
End states	[4, 12]]
Relevant behaviour paths	[1, 3, 7, 9, 12] and [1, 5, 6, 11, 7, 9, 12]
Behaviour description	The *Intensity of participation rate* which is defined by the three quantities influences *Stakeholder participation*. *Stakeholder participation* shows an interesting behaviour: when the *Intensity of participation rate* is set to <Plus>, the value stabilizes first, then gets a positive derivative and then starts to increase; this can be interpreted as the time that is needed for *Stakeholder participation* to be established in a community.

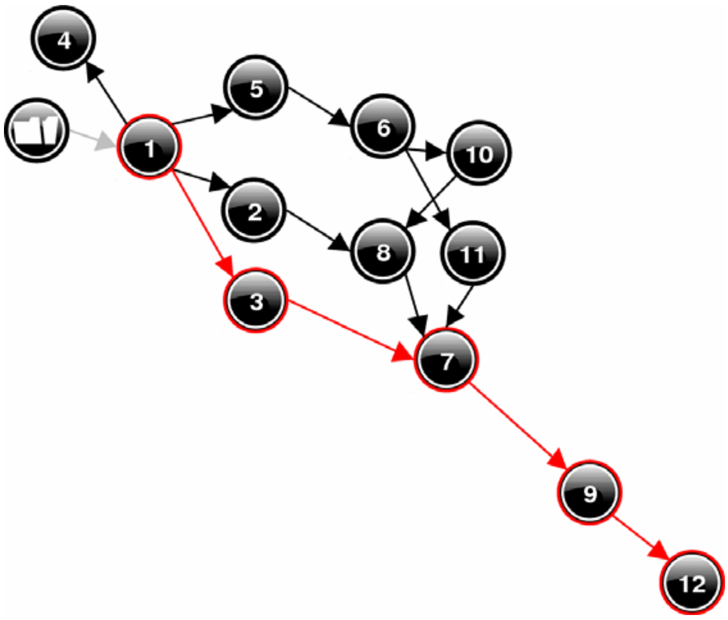


Figure 24: Behaviour graph obtained in a simulation of the sub-model "What affects stakeholder participation".

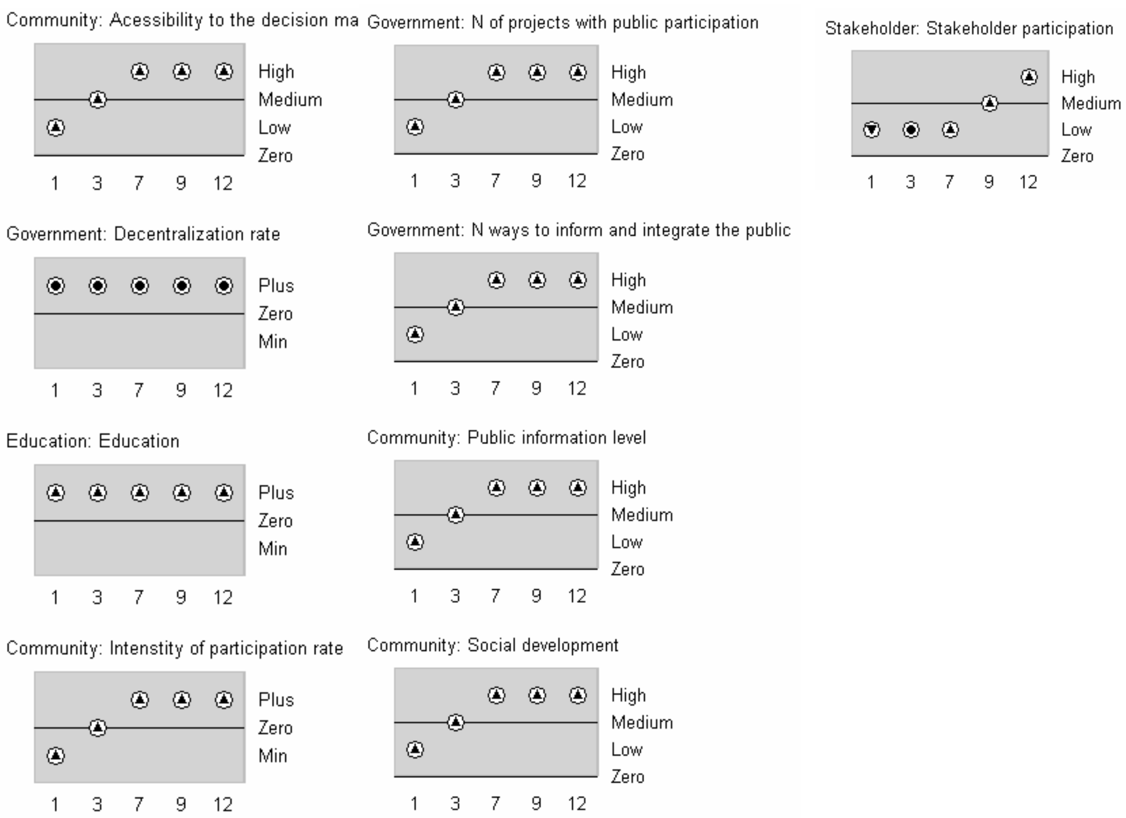


Figure 25: Value history diagrams of the quantities in the described behaviour path of the simulation of the sub-model "What affects stakeholder participation".

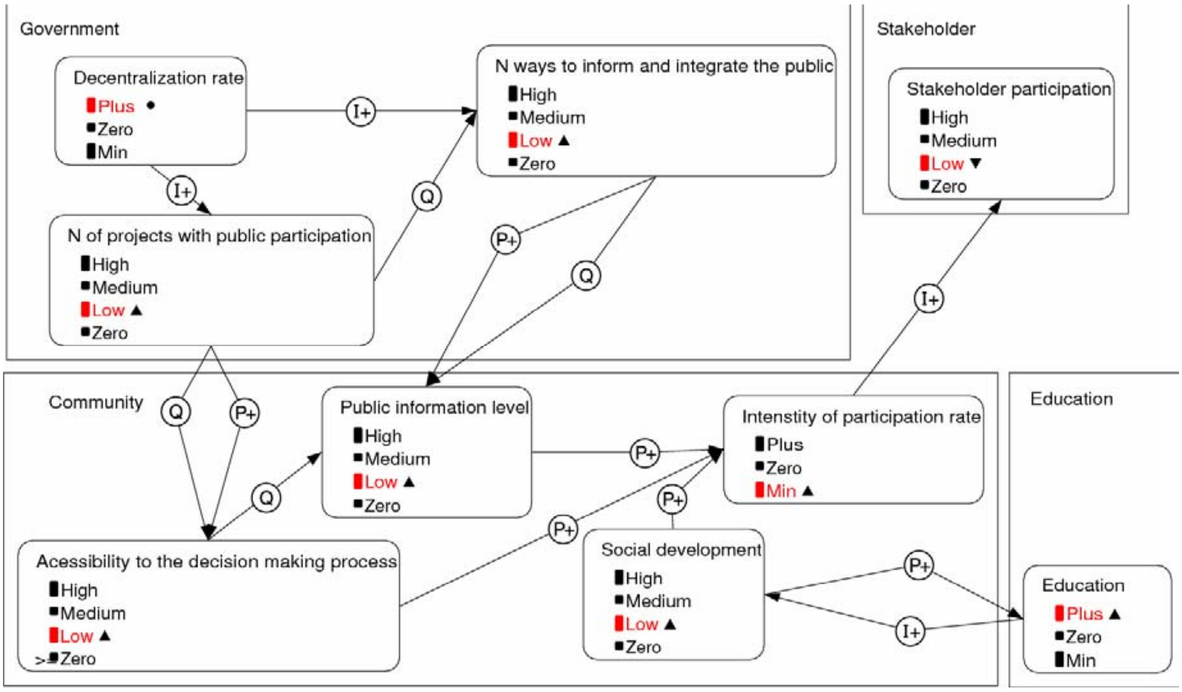


Figure 26: Detailed representation of the causal model in state 1 of the simulation of the sub-model "What affects stakeholder participation".

2.5.2.2 Scenario "Resources spent for community driven development"

This scenario explores the idea that resources are only spent for sustainable actions, when the process is driven by the community; this is reflected by the Investment for community driven development which is positively influenced by Stakeholder integration. (Fig. 27). Figs. 28-30 represent the behaviour graph, the value history and the causal model oft state one of the "Resources spent for community driven development" scenario.

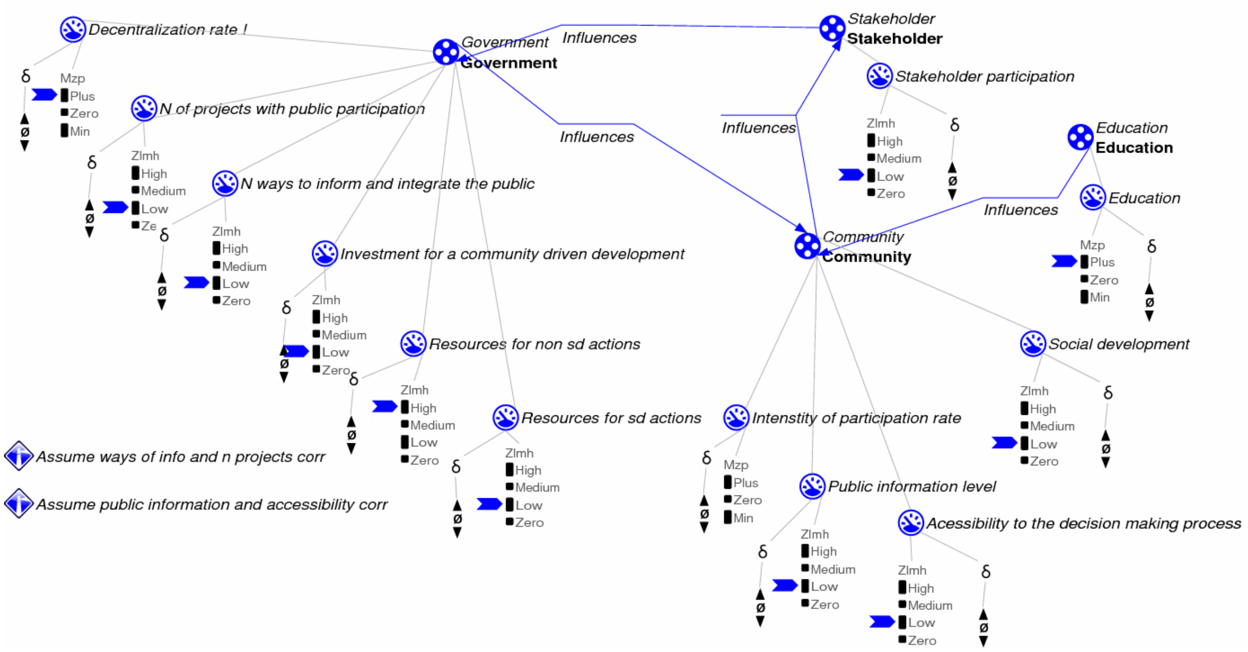


Figure 27: Initial scenario "Resources for community driven development".

Table 8: Simulation summary "Resources for community driven development".

Scenario name	"What affects resources spent for sd and non sd actions"
Full simulation	42 states
Initial states	[1]
End states	[6, 30]
Relevant behaviour paths	[1, 5, 9, 13, 30]
Behaviour description	The quantities related to the *Intensity of participation rate* develop together at the same time in the same direction; the *Intensity of participation rate follows accordingly* influencing positively stakeholder integration, which triggers the *Resources spend for a community driven development*.

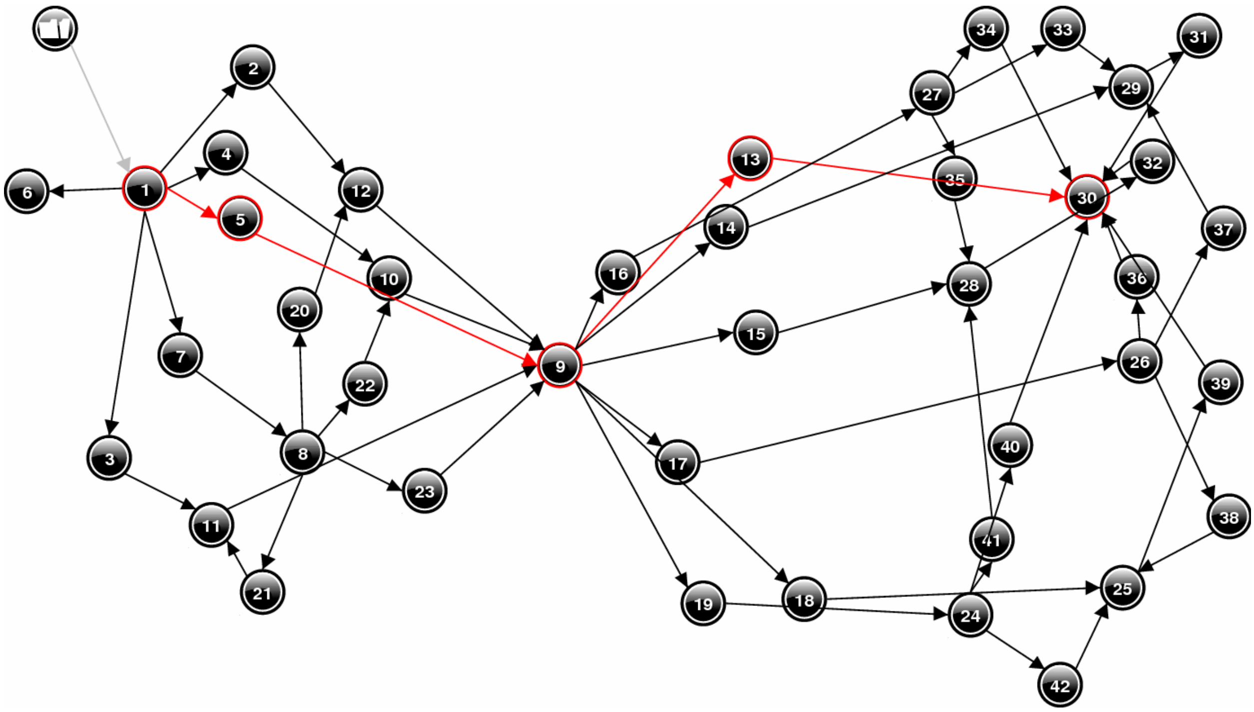


Figure 28: Behaviour graph obtained in a simulation of the scenario "What affects resources spent for SD and non SD actions".

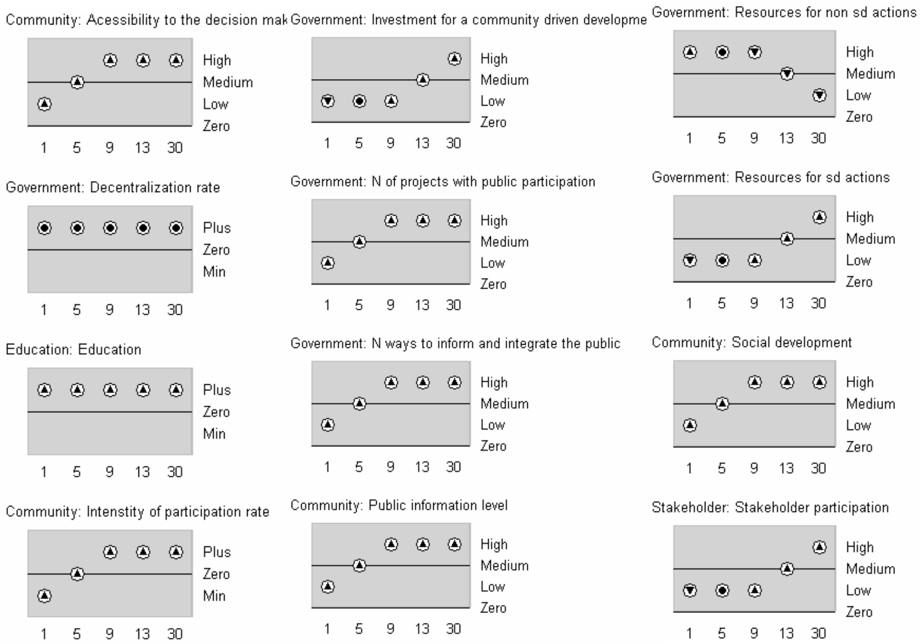


Figure 29: Value history diagrams of the quantities in the described behaviour path of the simulation of the scenario "What affects resources spent for SD and non SD actions".

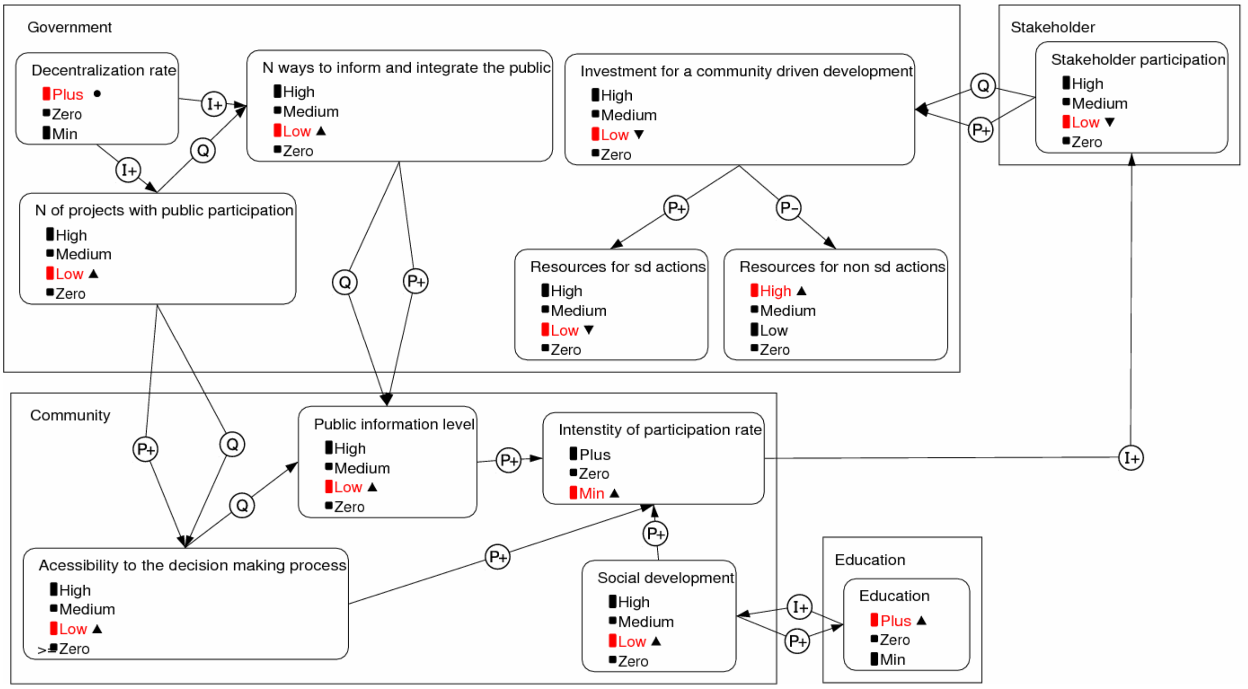


Figure 30: Detailed representation of the causal model in state 1 of the simulation of the scenario "What affects resources spent for SD and non SD actions".

2.6 Sub-model "Development and implementation of sustainability development plans"

The sub-model "Development and implementation of sustainability development plans" (DISDP) explores, under which circumstances high quality sustainability plans can be achieved. *Process understanding and technological solutions, Planner's preparedness and Stakeholder participation* define the *Quality of sustainability plans*. The potential value combinations were again pre-defined in tables and implemented a bunch of model fragments. Using the simulations supported by this model it should be possible to answer the following questions: *what are the circumstances for the development of high quality sustainability development plans.*

2.6.1 Model fragments

This model consists of 10 model fragments, six of them being static, four of them being processes.

2.6.1.1 "Stakeholder participation influences development plan"

This MF shows the influence of *Stakeholder participation* on the *Quality of sustainability plans* (Fig. 31).

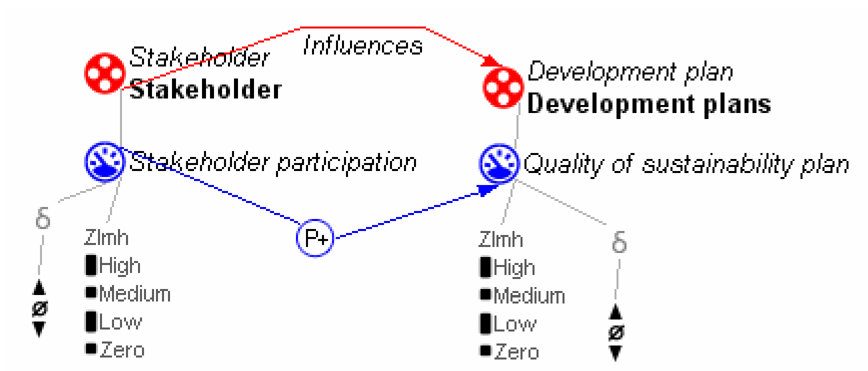


Figure 31: Static model fragment "Stakeholder participation influences development plan".

2.6.1.2 “Assume all factors influence development plan”

Based on 2.6.1.1 this static model fragment introduces all influences on the *Quality of sustainability plans (Stakeholder participation, Process understanding and technical solutions, Planners preparedness)* via an assumption (“Assume all factors influence development plan”) (Fig. 32).

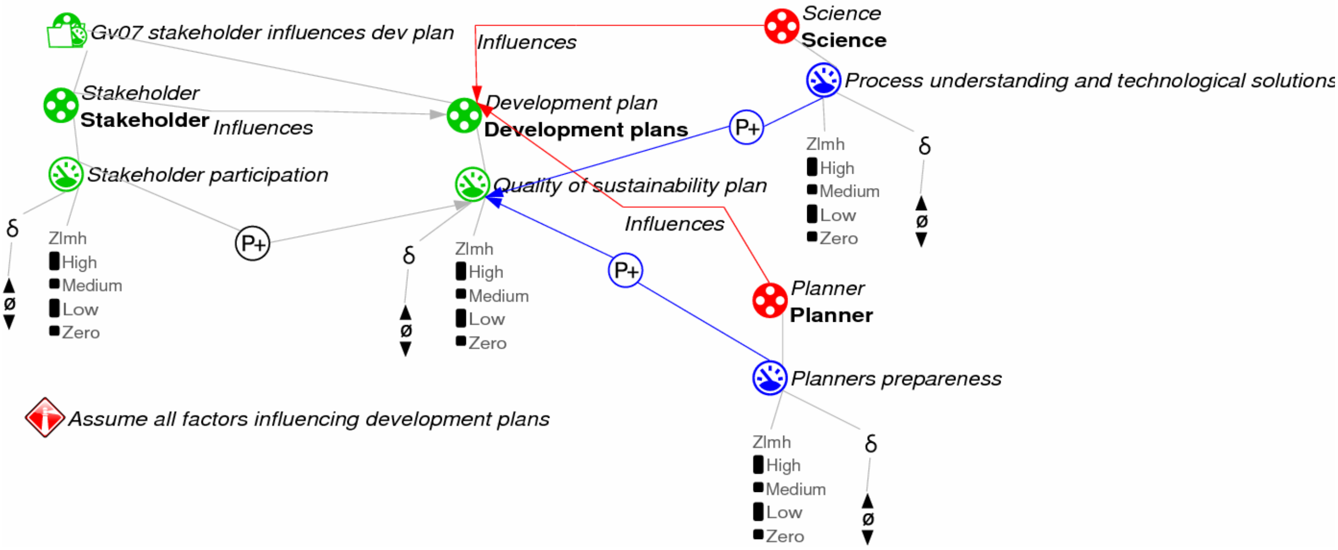


Figure 32: Static model fragment “Assume all factors influence development plan”.

2.6.1.3 “Assume all factors influence development plan and are corresponding”

Based on 2.6.1.1 this static model fragment introduces all influences (that are defined to be corresponding) on the *Quality of sustainability plans (Stakeholder participation, Process understanding and technical solutions, Planners preparedness)* via an assumption (“Assume all factors influence development plan and are corr”) (Fig. 33).

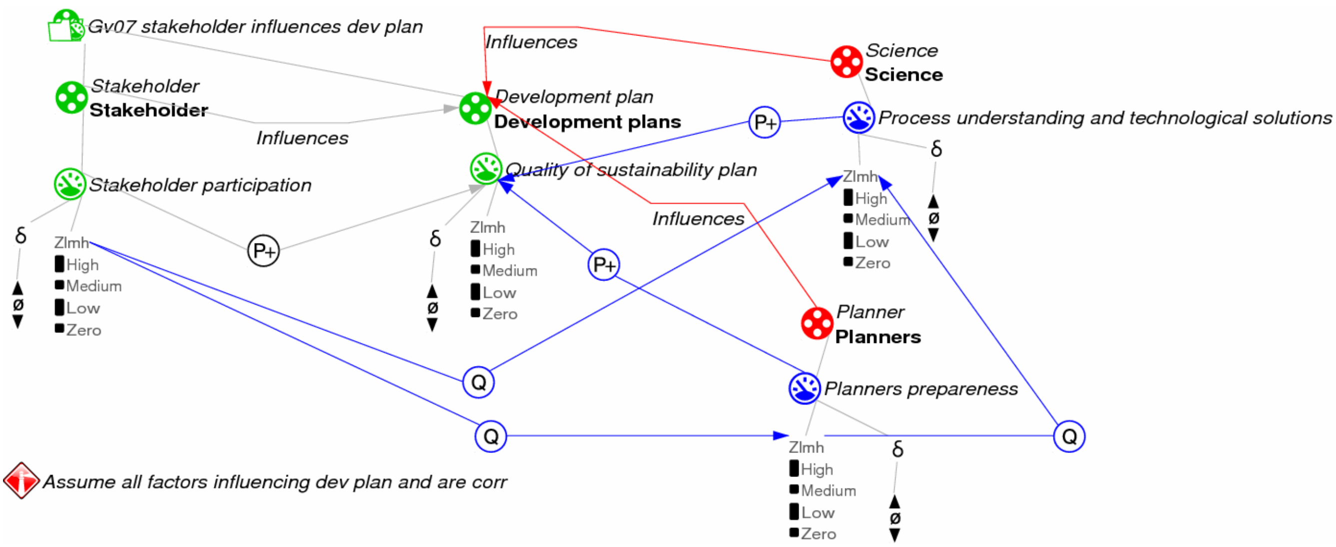


Figure 33: Static model fragment “Assume all factors influence development plan and are corresponding”.

2.6.1.4 “Scientific involvement rate configuration”

This static model fragment describes the configuration relevant for the integration of science for the development of sustainability plans; it uses the quantities *Scientific involvement rate* and *Process understanding and technical solutions* (Fig. 34).

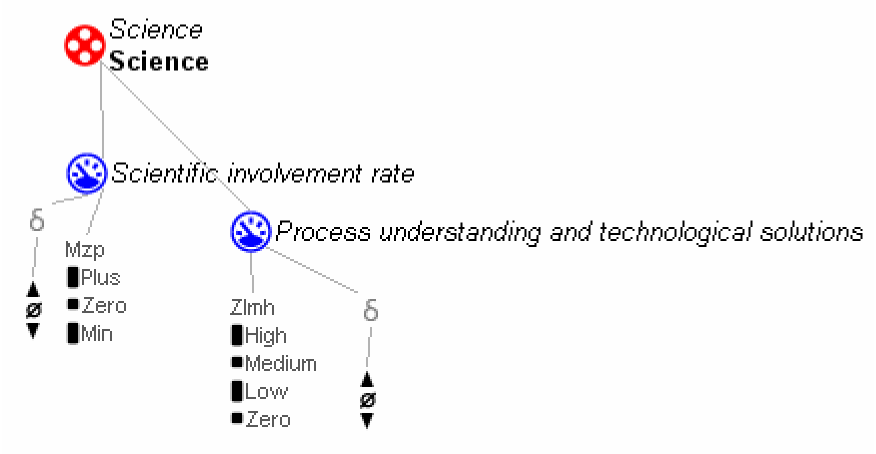


Figure 34: Static model fragment “Scientific involvement config”.

2.6.1.5 “Planner preparedness configuration”

This static model fragment describes the configuration relevant for the preparedness of planners to contribute to the development of sustainability plans; it uses the quantities *Qualification rate* and *Planners preparedness* (Fig. 35).

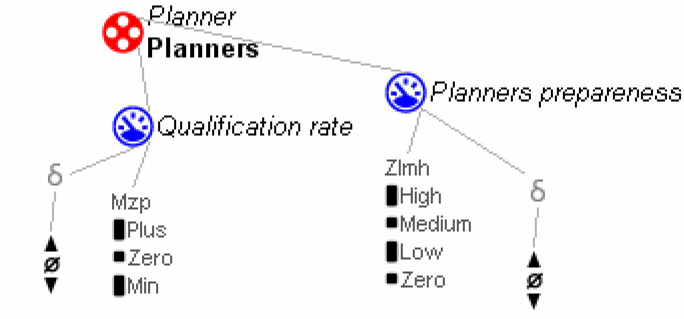


Figure 35: Static model fragment “Planner preparedness configuration”.

2.6.1.6 “Assume all factors influence development plan, stakeholder participation low”

This static model fragment is the first one of a large amount of model fragments, where the different value combinations for *Stakeholder participation* and *Process understanding and technical solutions* and *Planners preparedness* are pre-defined with a specific influence on the *Quality of sustainability plans* (Tab. 7). Here we start our definitions setting *Stakeholder participation* to <Low> (Fig. 36).

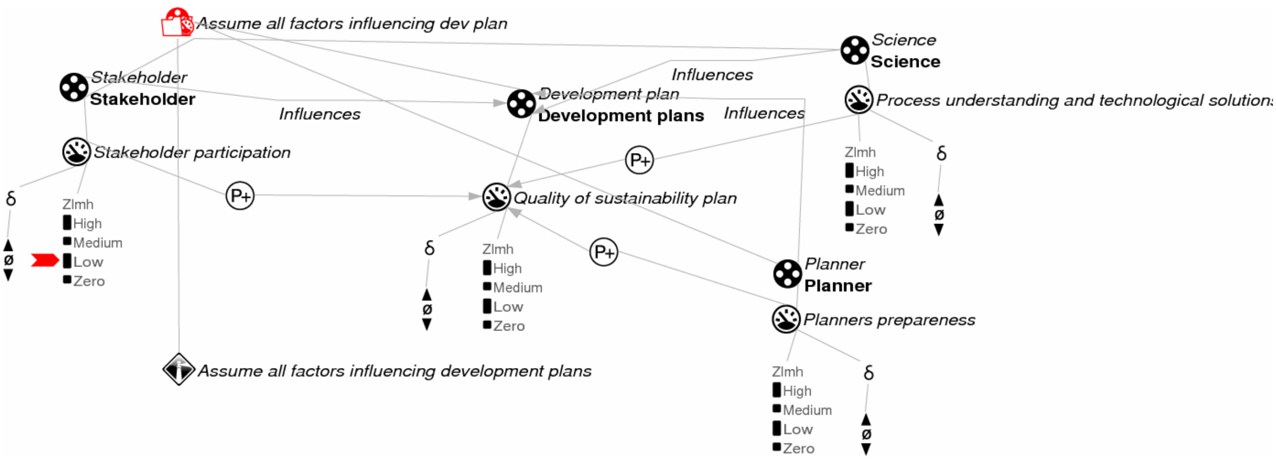


Figure 36: Static model fragment “Assume all factors influence development plan, Stakeholder participation low”.

2.6.1.7 “Assume all factors influence development plan, stakeholder participation low, Process understanding and technical solutions low”

In this static model fragment based on 2.6.1.7 additionally to set *Stakeholder participation* to <Low>, the *Process understanding and technical solutions* is also set to <Low> (Fig. 37).

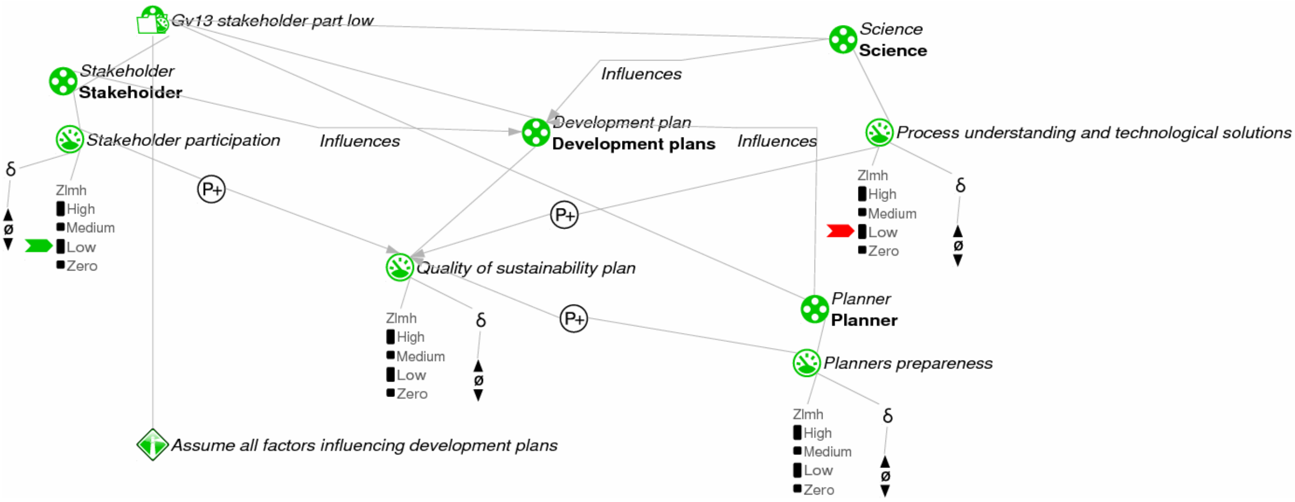


Figure 37: Static model fragment “Assume all factors influence development plan, Stakeholder participation low, Process understanding and technical solutions low”.

2.6.1.8 “Assume all factors influence development plan, stakeholder participation low, Process understanding and technical solutions low”

Finally in model fragment based on 2.6.1.7 additionally to setting *Stakeholder participation and Process understanding and technical solutions Public information level* to <Low>, *Planners preparedness* is set to <Equal greater zero> which yields a *Quality of sustainability plan* of <Low> (Fig. 38).

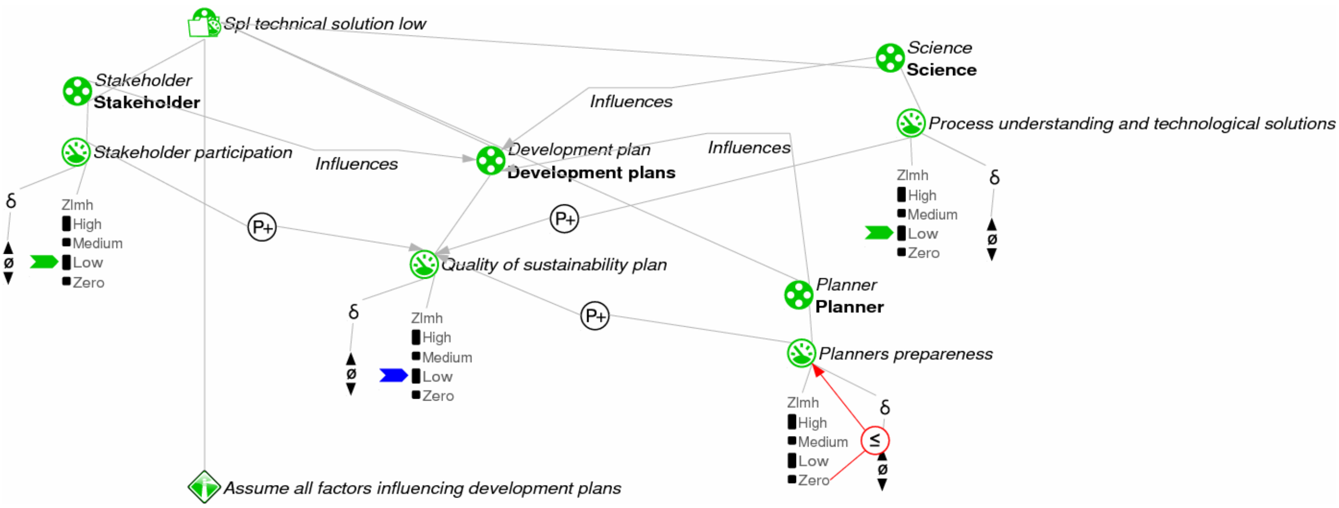


Figure 38: Static model fragment “Assume all factors influence development plan, Stakeholder participation low, Process understanding and technical solutions low, Planners preparedness greater equal zero – Quality of sustainability plans low”.

Table 9: All possible value combinations of the quantities *Stakeholder participation, Process understanding and technical solutions, planners preparedness* that compose the *Quality of sustainability plans*; these potential value combinations have been defined by expert judgement and were implemented in single model fragments; the value combination shown in Figs. 36-38 are shown in yellow.

Stakeholder participation	Technical solutions	Planners preparedness	Quality of sustainability plans
h	**h**	**h**	**h**
h	**h**	**m**	**h**
h	h	l	m
h	h	z	l
h	**m**	**h**	**h**
h	m	m	m
h	m	l	m
h	m	z	l
h	l	h	m
h	l	m	l
h	l	l	l
h	l	z	l
h	z	h	l
h	z	m	l
h	z	l	l
h	z	z	z
m	**h**	**h**	**h**
m	h	m	m
m	h	l	m
m	h	z	l
m	m	h	m
m	m	m	m
m	m	l	m
m	m	z	l
m	l	h	l
m	l	m	l
m	l	l	l
m	l	z	l
m	z	h	l
m	z	m	l
m	z	l	l
m	z	z	z
l	h	h	l
l	h	m	l
l	h	l	l
l	h	z	l
l	m	h	l
l	m	m	l
l	m	l	l
l	m	z	l
l	l	h	l
l	l	m	l
l	l	l	l
l	l	z	l
l	z	h	l
l	z	m	l
l	z	l	z
l	z	z	z
z	h	h	l
z	h	m	l
z	h	l	l
z	h	z	l
z	m	h	l
z	m	m	l
z	m	l	l
z	m	z	l
z	l	h	l
z	l	m	l
z	l	l	z
z	l	z	z
z	z	h	l
z	z	m	l
z	z	l	z
z	z	z	z

2.6.1.9 “Government action rate influenced”

This model fragment captures the factors, which influence the *Government action rate*: *Quality of sustainability plans, Group pressure* and *Resistance against measures* (Fig. 39).

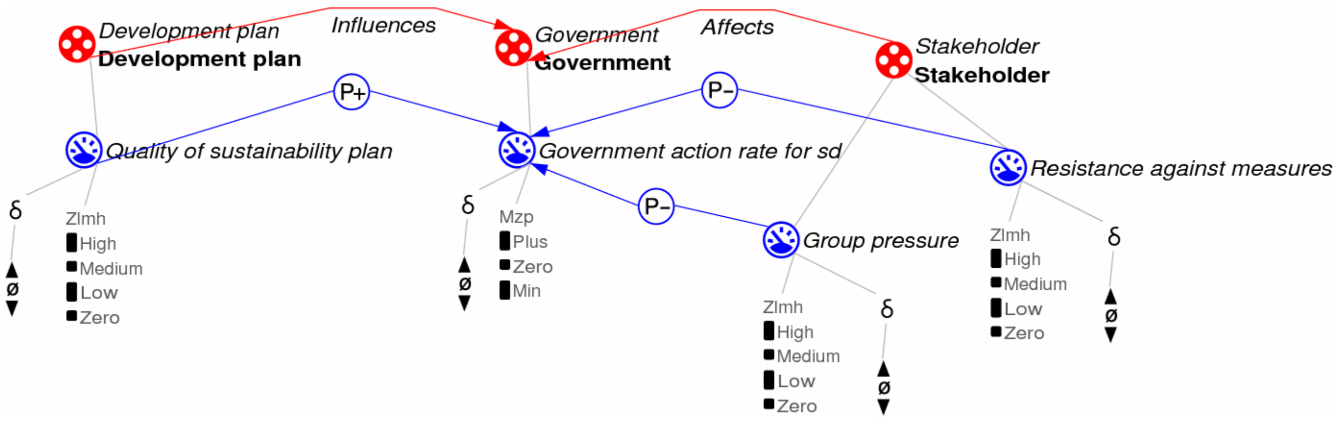


Figure 39: Static model fragment “Government action rate influenced”.

2.6.1.10 “Private interests build up process; stakeholder participation defines resistance against measures”

This process model fragment shows how the *Private interest build up rate* influences the *Group pressure*; both are set conditional and only appear in the scenario when explicitly mentioned. Additionally *Stakeholder participation* negatively influences *Resistance against measures*; the relationship is defined via directed correspondences (Fig. 40).

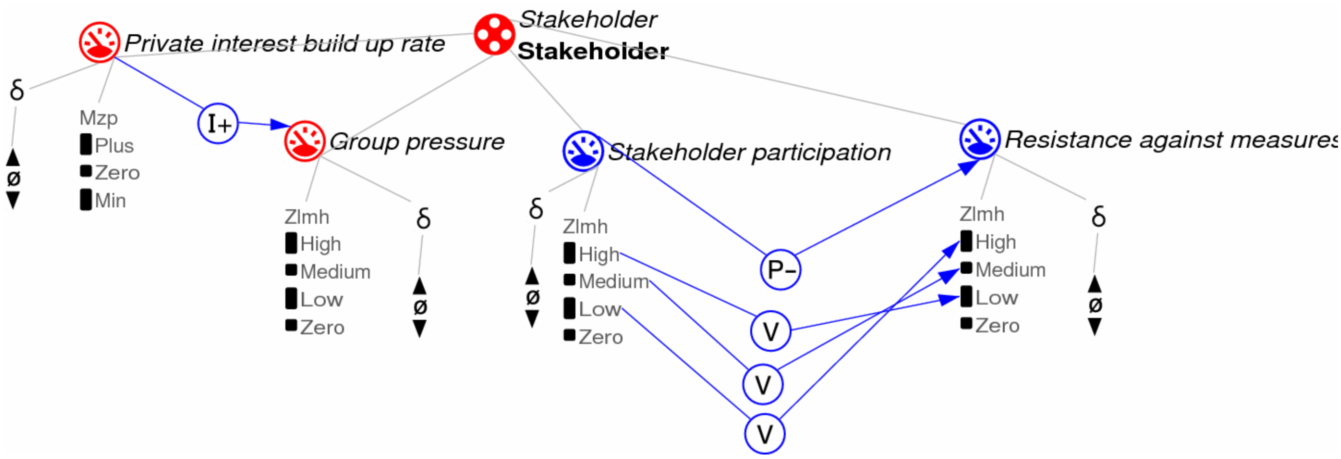


Figure 40: Process model fragment “Private interests build up process; Stakeholder participation defines Resistance against measures”.

2.6.1.11 “Private interests build up process; stakeholder participation defines resistance against measures”

This static model fragment is the first one of a large amount of model fragments, where the different value combinations for *Quality of development plan* and *Group pressure* and *Resistance against measures* are pre-defined with a specific influence on the *Government action rate for sd* (Tab. 8). Here we start our definitions setting *Quality of sustainability plans* to <Low> (Fig. 41).

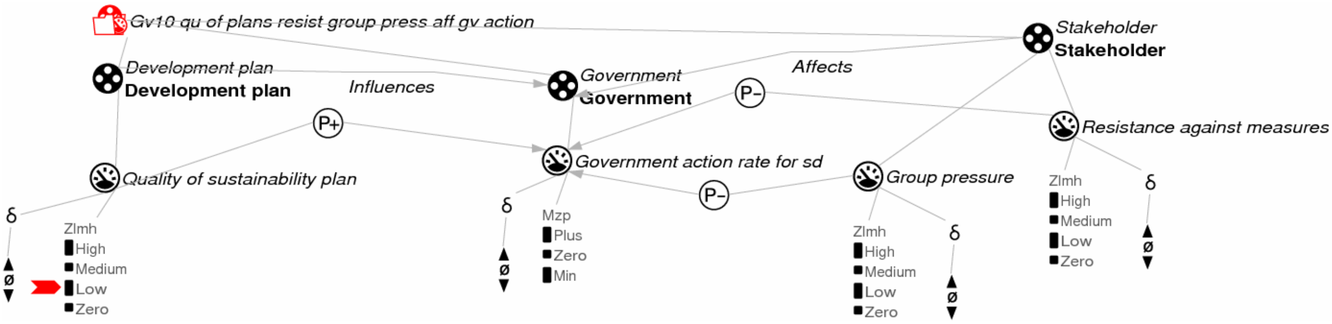


Figure 41: Static model fragment "Government action rate influenced, Quality of plans low".

2.6.1.12 "Government action rate influenced, quality of plans low, Resistance against measures high"

In this static model fragment based on 2.6.1.11 additionally to set *Quality of sustainability plans* to <Low>, the *Resistance against measures* is also set to <High> (Fig. 42).

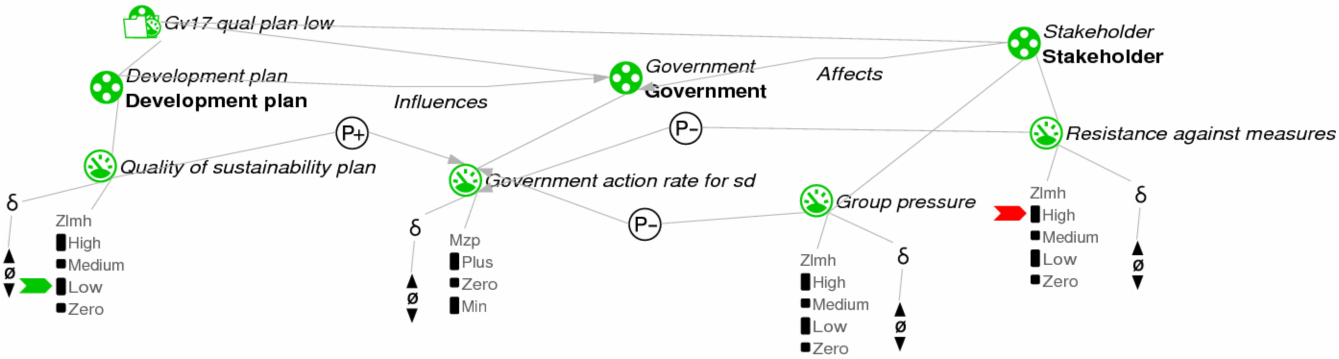


Figure 42: Static model fragment "Government action rate influenced, Quality of plans low, Resistance against measures high".

2.6.1.13 "Government action rate influenced, Quality of plans low, Resistance against measures high, Group pressure high – Government action rate for sd greater equal medium"

Finally in model fragment based on 2.6.1.12 additionally to setting *Quality of sustainability plans* to <Low> and *Resistance against measures* to <High>, *Group pressure* is set to <Equal greater medium> which yields a *Government action rate* of <Zero> (Fig. 37).

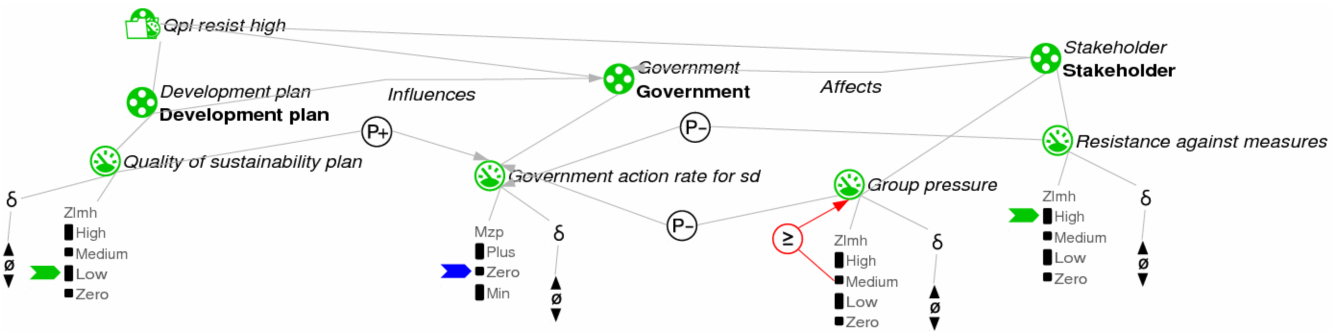


Figure 43: Government action rate influenced, quality of plans low, Resistance against measures high, Group pressure equal greater medium – Government action rate for sd zero

Table 10: All possible value combinations of the quantities *Quality of sustainability plan*, *Resistance against measures* and *Group pressure* that compose the *Government action rate for SD* have been defined by expert judgement and were implemented in single model fragments; the value combination shown in Figs. 41-43 are shown in yellow.

Quality of sustainabilty	Resistance against measures	Group pressure	Gv action for SD
h	h	h	minus
h	h	m	z
h	h	l	z
h	h	z	z
h	m	h	minus
h	m	m	minus
h	m	l	z
h	m	z	z
h	l	h	minus
h	l	m	minus
h	**l**	**l**	**plus**
h	**l**	**z**	**plus**
h	z	h	minus
h	z	m	minus
h	**z**	**l**	**plus**
h	**z**	**z**	**plus**
m	h	h	minus
m	h	m	z
m	h	l	z
m	h	z	z
m	m	h	minus
m	m	m	minus
m	m	l	z
m	m	z	z
m	l	h	minus
m	l	m	minus
m	l	l	z
m	l	z	plus
m	z	h	minus
m	z	m	minus
m	z	l	z
m	z	z	plus
l	h	h	minus
l	h	m	z
l	h	l	z
l	h	z	z
l	m	h	minus
l	m	m	minus
l	m	l	z
l	m	z	z
l	l	h	minus
l	l	m	minus
l	l	l	minus
l	l	z	z
l	z	h	minus
l	z	m	minus
l	z	l	minus
l	z	z	z
z	h	h	minus
z	h	m	z
z	h	l	z
z	h	z	z
z	m	h	minus
z	m	m	minus
z	m	l	z
z	m	z	z
z	l	h	minus
z	l	m	minus
z	l	l	minus
z	l	z	z
z	z	h	minus
z	z	m	minus
z	z	l	minus
z	z	z	z

2.6.2 Scenarios and simulations

The sub-model “Development and implementation of sustainability development plans” (DISDP) has two scenarios, basically capturing the potential influences on the *Quality of sustainability plans* and at the end the influences on the *Government action rate for SD.*

2.6.2.1 “What affects the quality of sustainability plans”

With this scenario one can explore the effect of different influences on the *Quality of development plans* by changing rates yielding different value combinations for *Planners preparedness, Process understanding and technical solutions* and *Stakeholder participation influencing* the *Quality of development plans* as defined in Tab. 7. All rates are set rates are set as <Steady> and <Plus>.

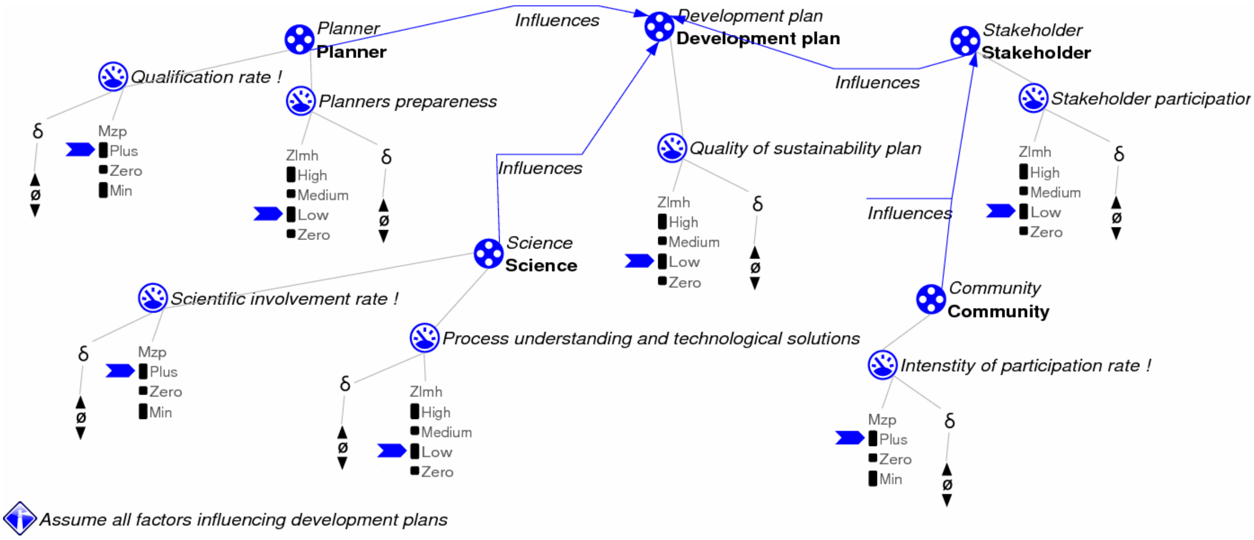


Figure 44: Scenario “What affects the quality of sustainability plans”.

Table 11: Simulation summary “What affects the quality of sustainability plans”.

Scenario name	“What affects the quality of sustainability plans”
Full simulation	22 states
Initial states	[1]
End states	[4, 5, 10, 12, 15, 16, 18, 20]
Relevant behaviour paths	[1, 3, 12] and [1, 6, 11, 18] and [1, 6, 11, 17, 12] and [1, 2, 13, 15] and [1, 2, 13, 16] and [1, 2, 13, 14, 12]
Behaviour description	The first path describes the shortest path of all three related quantities that define the quality of sustainability plans. All other paths represent different potential value combinations exploring the system, under which circumstances a high quality of development plans is achieved. This simulation allows for the exploration of the effect of different factors on the *Quality of sustainability plans*; via the quantity *Intensity of participation rate* it is linked to the scenario “What affects stakeholder participation”.

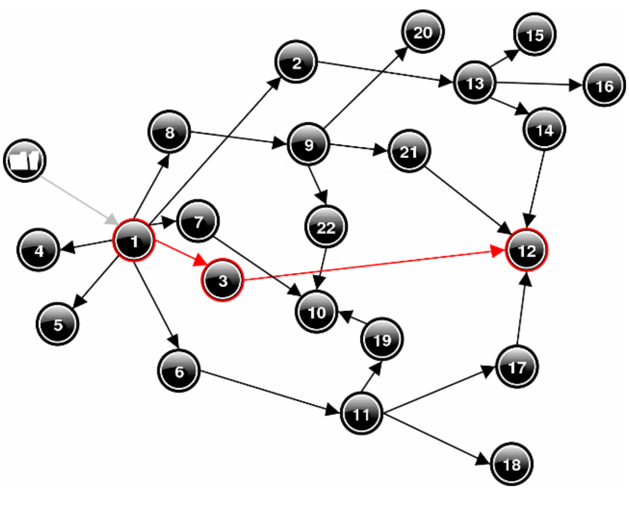


Figure 45: Behaviour graph obtained in a simulation of the scenario “What affects the quality of sustainability plans”.

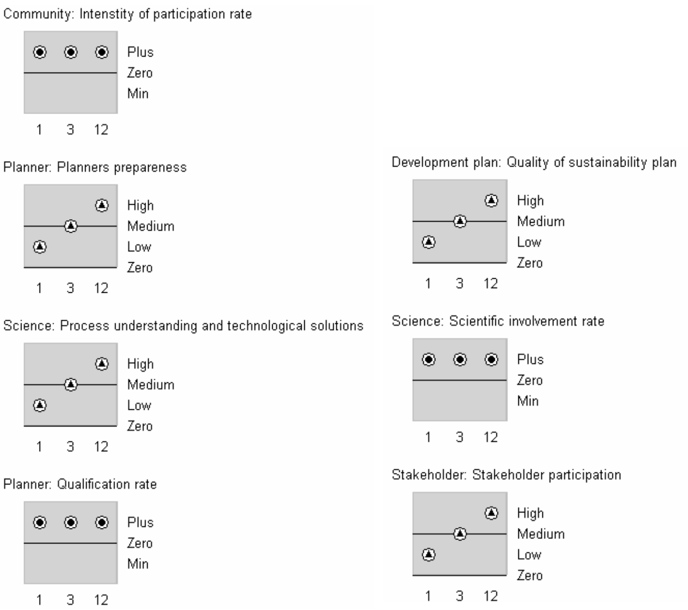


Figure 46: Value history diagrams of the quantities in the described behaviour path of the simulation of the scenario "What affects the quality of sustainability plans".

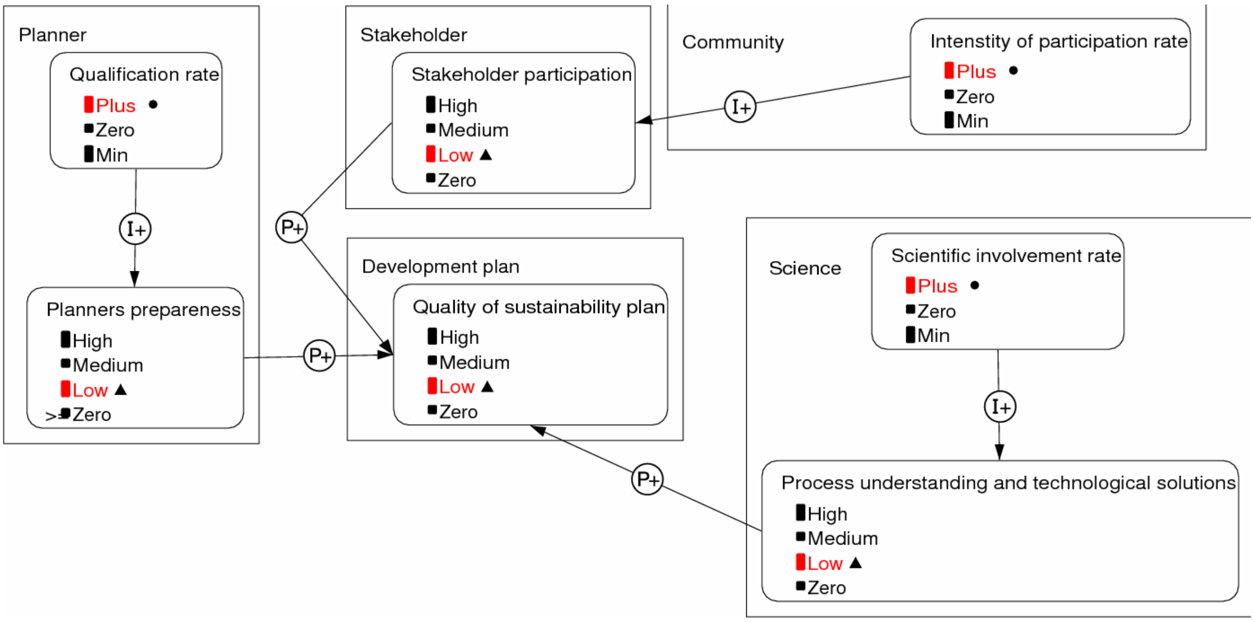


Figure 47: Detailed representation of the causal model in state 1 of the simulation of the scenario "What affects the quality of sustainability plans".

2.6.2.2 "What affects government action rate (without fear)"

With this scenario one can explore the effect of different influences on the *Government action rate* that is defined by different value combinations for *Group pressure, Resistance against measures* and *Quality of sustainability plans* (Tab. 8); the *Quality of sustainability plans* itself is defined by *Planners preparedness, Process understanding and technical solutions* and *Stakeholder participation influencing* the *Quality of development plans* (Tab. 7) and links this scenario to the scenario "What affects the quality of sustainability plans".

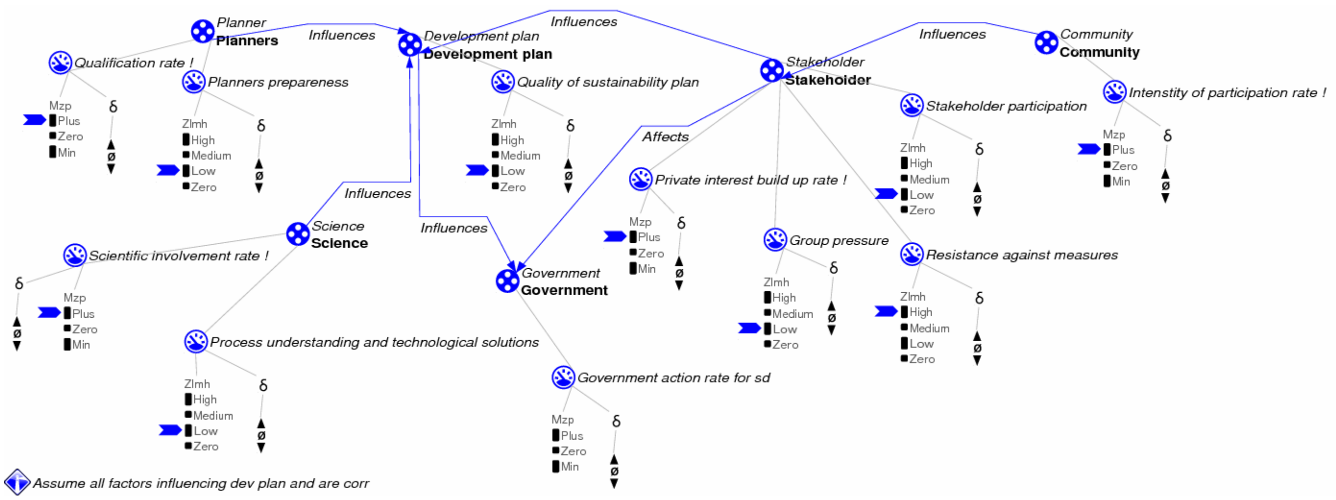


Figure 48: Scenario "What affects government action rate (without fear)".

Table 12: Simulation summary "What affects government action rate (without fear)".

Scenario name	"What affects government action rate (without fear)"
Full simulation	63 states
Initial states	[1,2,3]
End states	[1, 3, 5, 6, 7, 8, 11, 12, 14, 15, 16, 18, 19, 21, 26, 27, 48, 49, 52, 53, 54, 55, 56]
Relevant behaviour paths	[2, 17, 20, 50, 26] and [2, 17, 20, 50, 27]
Behaviour description	The Government action rate for SD only gets a positive value in two end states (26 and 27), describing how complex the influences on the system are. Fig. 50 shows the different possible value combinations in the end states.

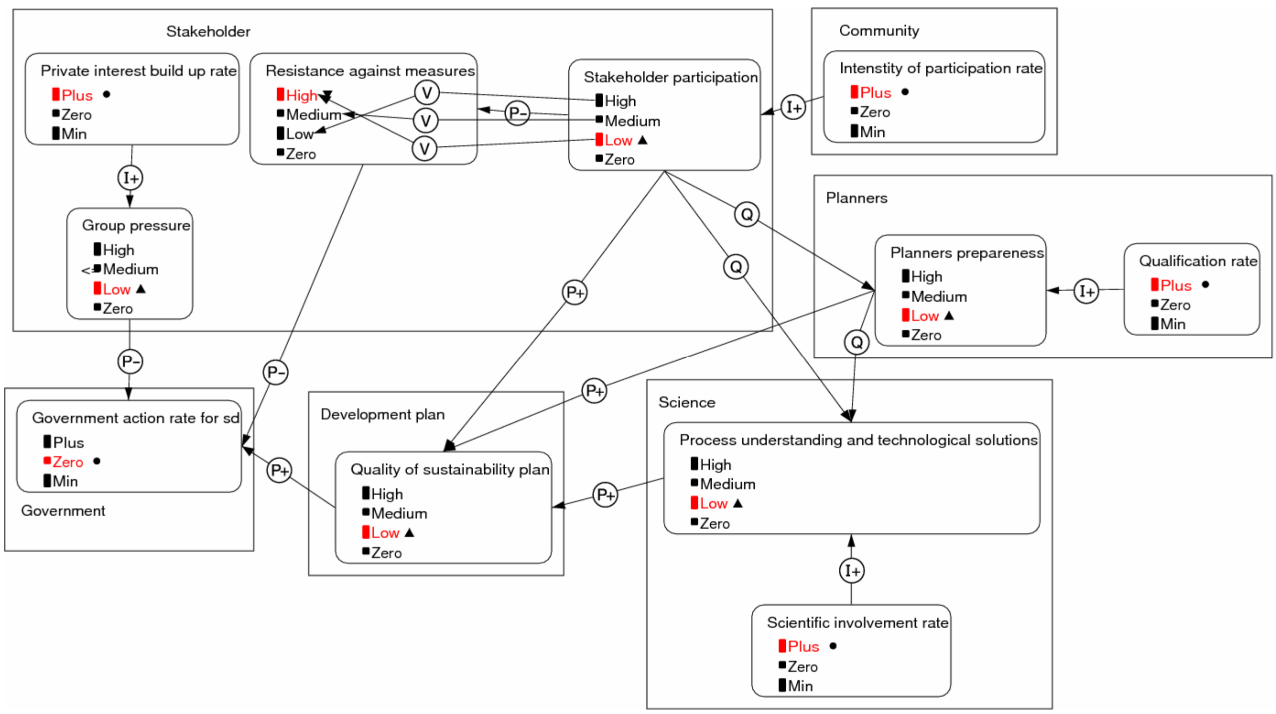


Figure 49: Detailed representation of the causal model in state 1 of the simulation of the scenario "What affects government action rate (without fear)".

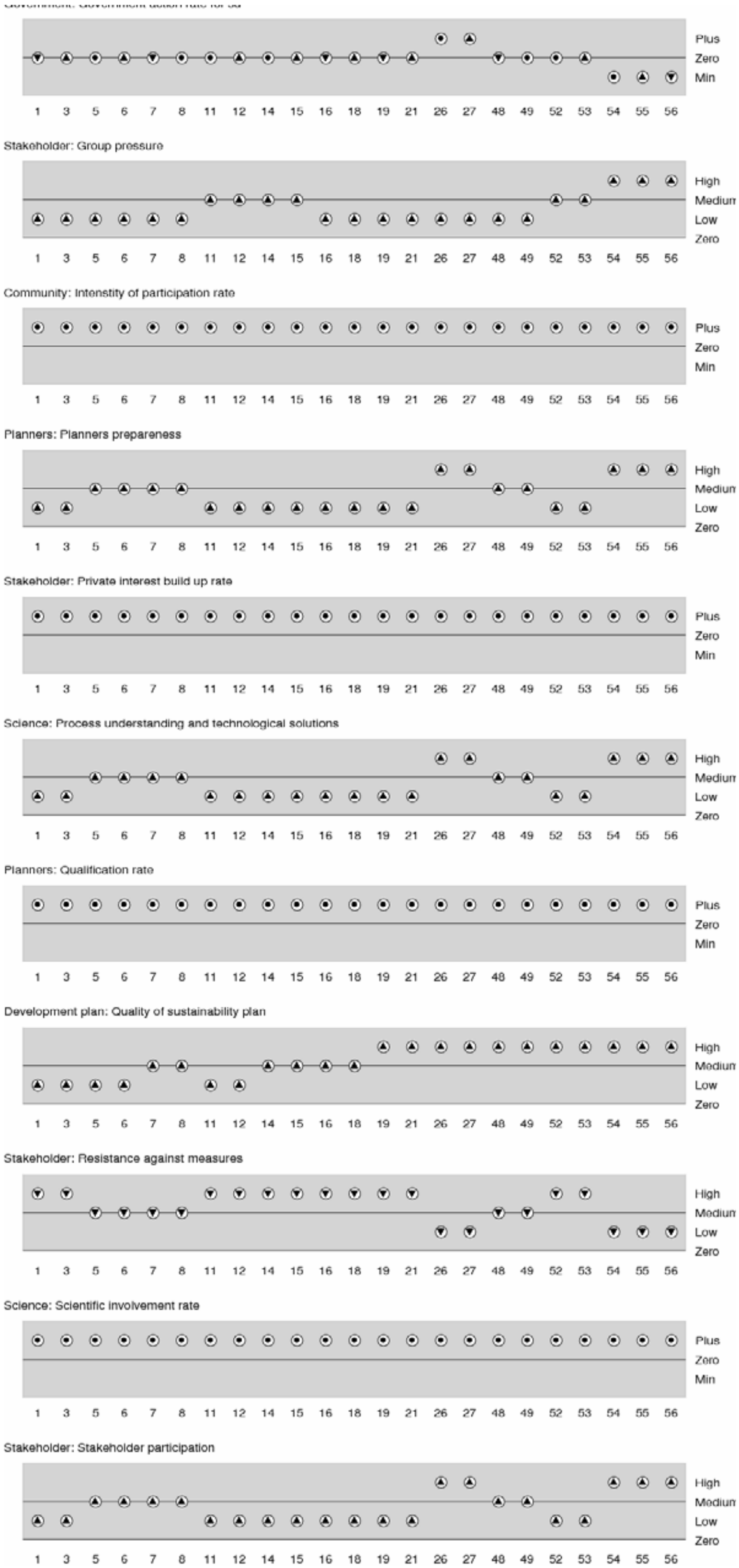


Figure 50: Value diagrams of the quantities in the end states of the scenario "What affects government action rate (without fear)".

2.7 Sub-model "Government influences ecological integrity of river basin and human well being"

The sub-model "Government influences ecological integrity of river basin and human well being" (GEH) explores the important issues of ecological integrity and human well being on a catchment level. The sub-models should provide answers, given the other sub-models, which factors are relevant to achieve a high ecological integrity and human well being in a river catchment.

2.7.1 Model fragments

The GEH sub-model consists of eight model fragments, five of them being static and three being processes.

2.7.1.1 "Government action configuration"

This model fragment captures the idea of a feedback loop between *Sustainable* and *Non sustainable actions* on the *Government action rate for Sd* (Fig. 51); for example when *Sustainable actions* are at <Maximum>, there is no need to further have a positive *Government action rate for SD*.

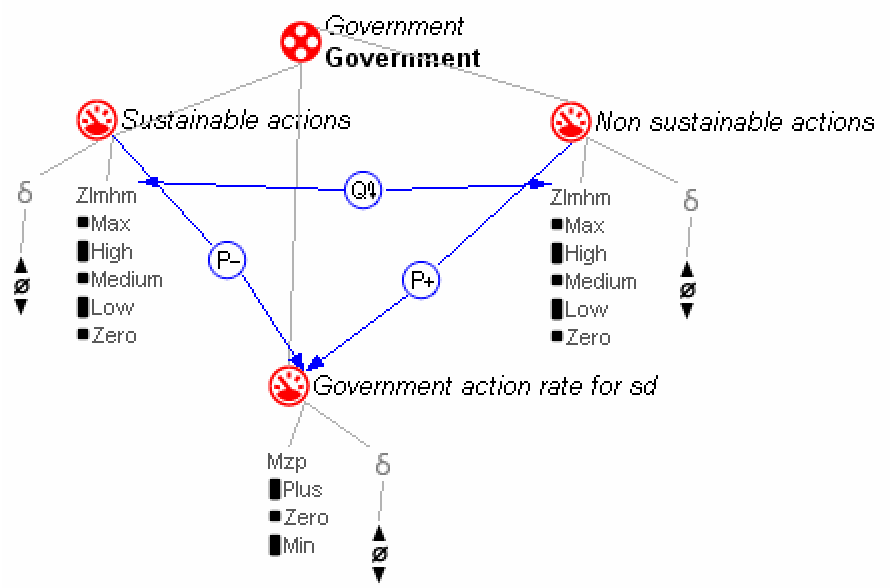


Figure 51: Static model fragment "Government action configuration".

2.7.1.2 "Ecological integrity configuration"

This static model fragment captures quantities related to the *Ecological integrity* of the river basin (Fig. 52).

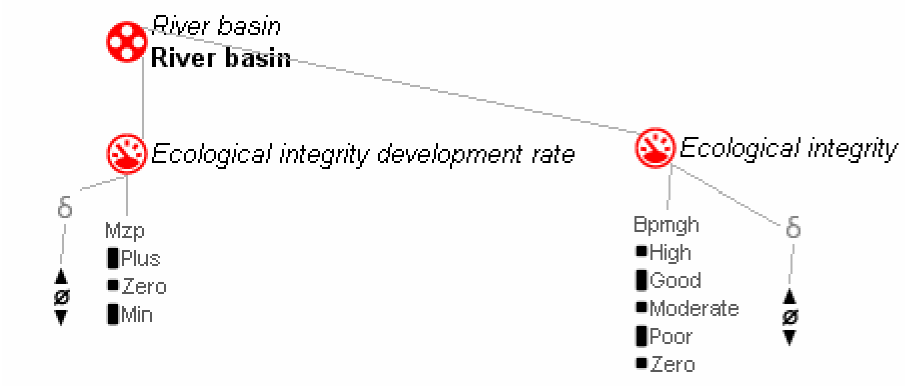


Figure 52: Static model fragment "Ecological integrity configuration".

2.7.1.3 "Human well being configuration"

This static model fragment captures the basic quantities related to human well being in the community inhabiting the river catchment. It uses the quantities *Number of negative factors, Number of positive factors* and *Human well being*; all quantities are set as conditional and only appear in a scenario, when explicitly mentioned (Fig. 53).

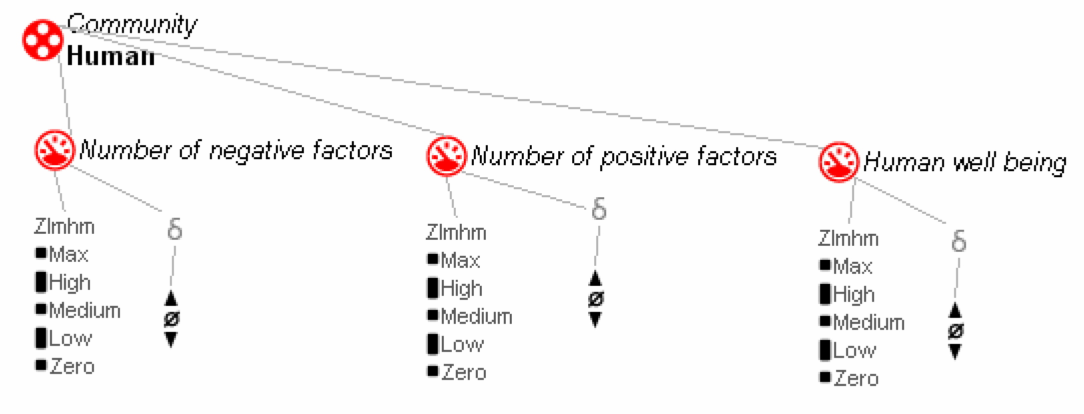


Figure 53: Static model fragment "Human well being configuration".

2.7.1.4 "Ecological integrity change process"

This process model fragment describes how the *Ecological integrity* of the River basin is influenced by the *Ecological development rate*; this rate is calculated by the relationship of *Non sustainable actions* to *Sustainable actions* (Fig. 54).

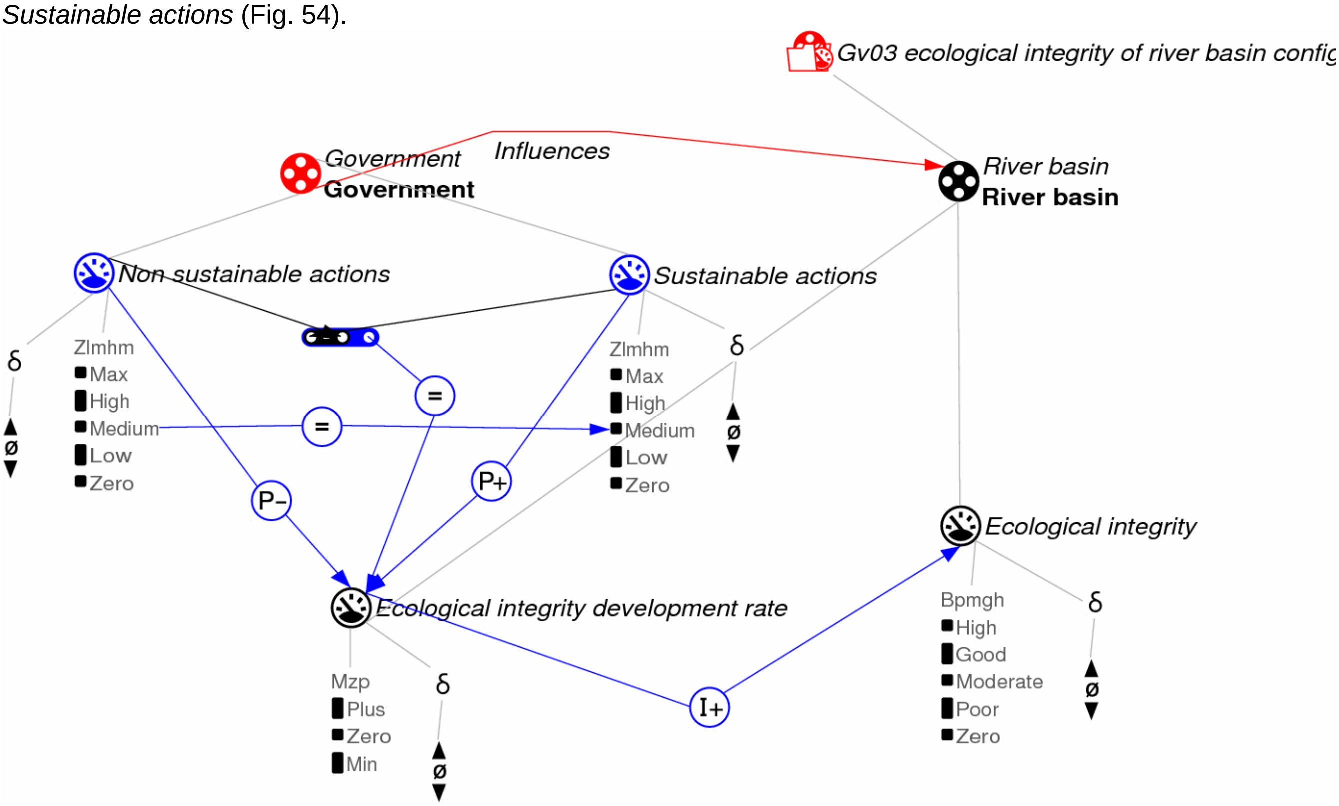


Figure 54: Process model fragment "Ecological integrity change process".

2.7.1.5 “Government affects human well being”

This static model fragment describes how the *Number of negative and positive factors* is influenced by *Sustainable and non sustainable actions*. *Non sustainable actions* and *Sustainable actions* are related via an inverse correspondence (Fig. 55).

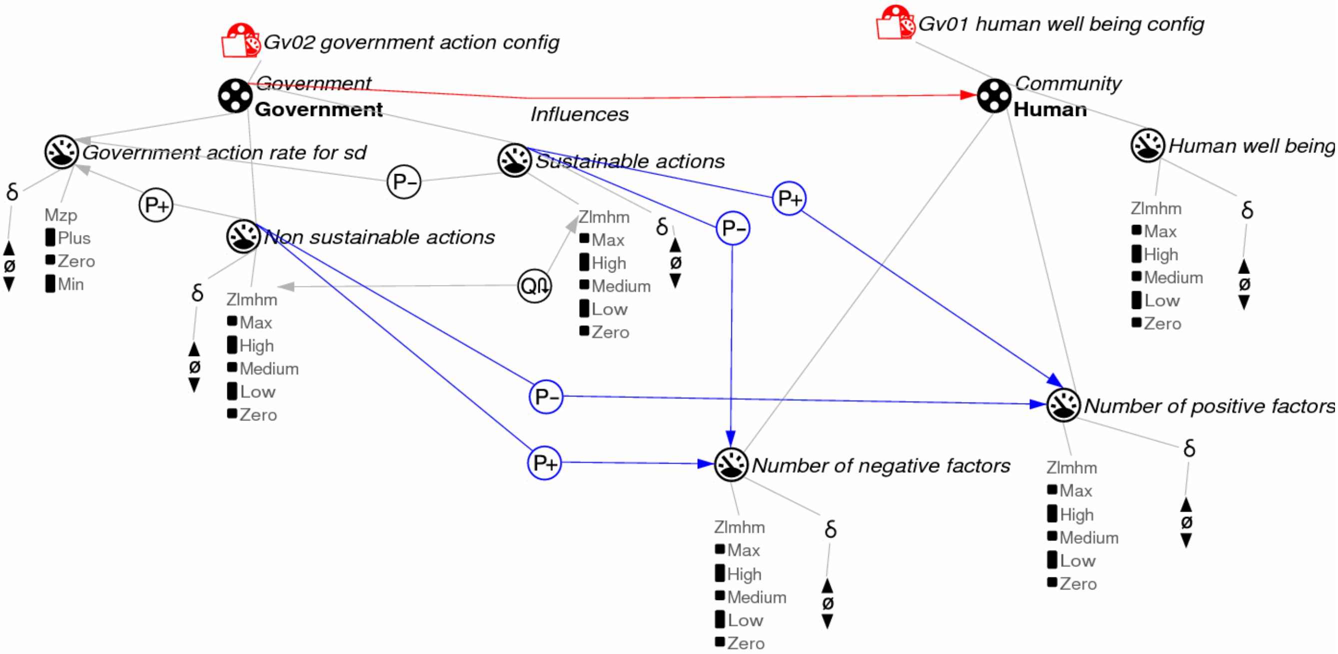


Figure 55: Static model fragment “Government affects human well being”

2.7.1.6 “Assume sustainable and non sustainable actions corresponding to positive and negative factors”

This static model fragment is based on 2.7.1.5 and introduces the assumption, that *Sustainable and non sustainable actions* are linked to the *Number of positive and negative factors* via directed correspondences (Fig. 56).

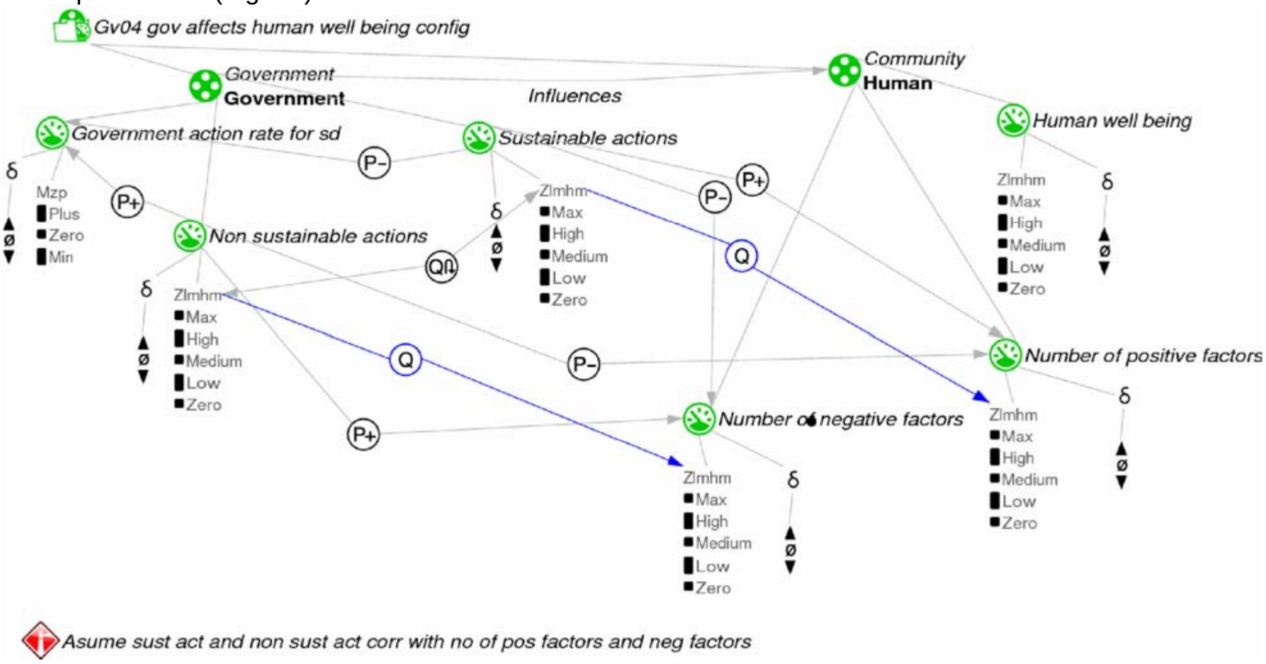


Figure 56: Static model fragment “Assume sustainable and non sustainable actions corresponding to positive and negative factors”.

2.7.1.7 "Human well being development process"

This model fragment re-uses the MF described in 2.7.1.6 introducing the "Human well being development process"; the *Human well being development rate* is calculated by *Number of negative and positive factors* and influences the *Human well being (Fig. 57)*.

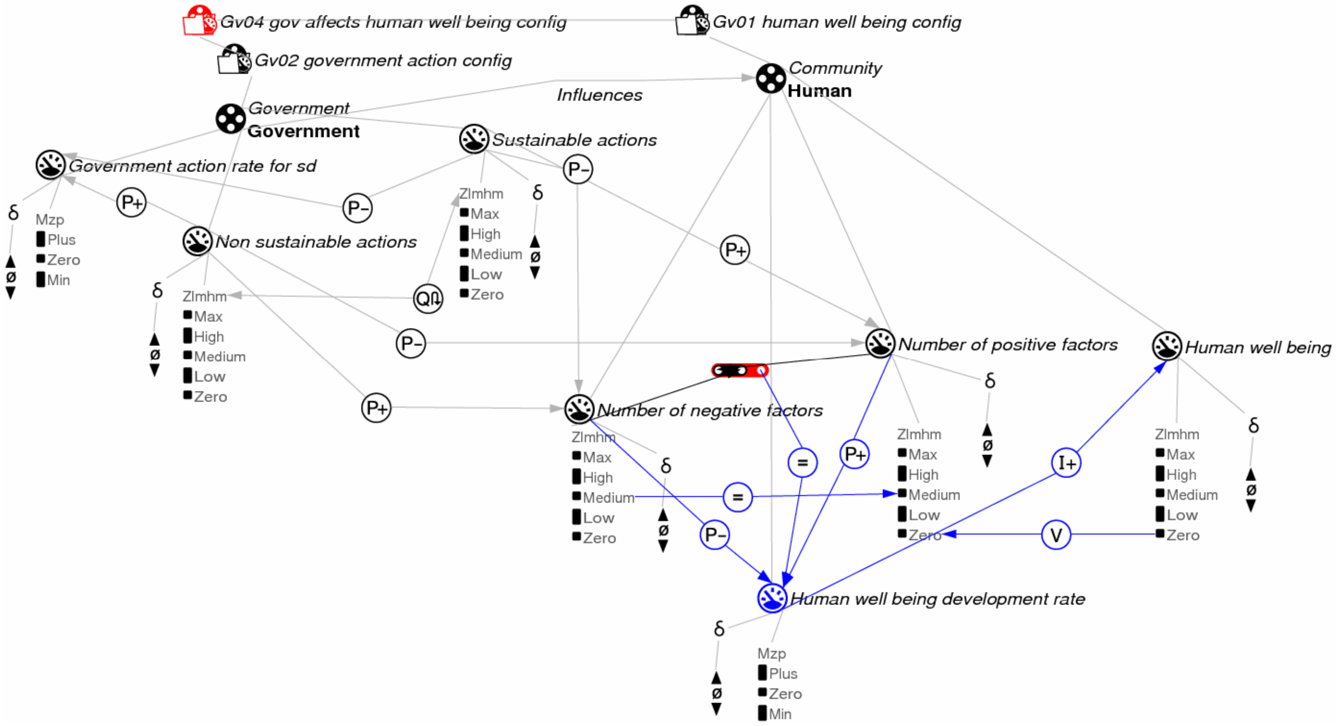


Figure 57: Process model fragment "Human well being development process".

2.7.1.8 "Government action process"

This process model fragment shows how the *Sustainable and Non sustainable actions* are influenced by the *Government action rate for SD*; all quantities are set as conditional, only appearing in the simulation when explicitly mentioned in the scenario.

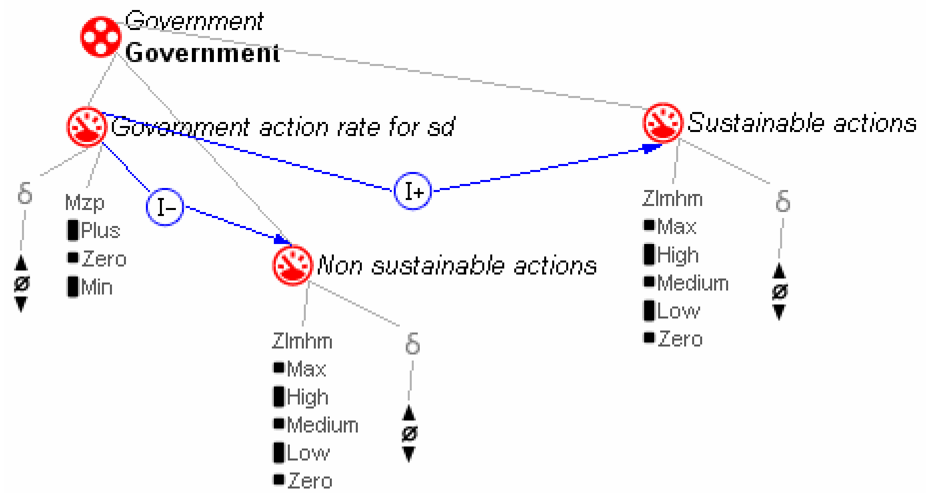


Figure 58: Process model fragment "Government action process".

2.7.2 Scenarios and simulations

The GEH sub-model consists out of two scenarios, exploring the idea of ecological integrity and human well being based on sustainable and non sustainable actions.

2.7.2.1 “Ecological development”

This scenario is more or less the end-point of the whole process described within the other sub-models. Based on different outcomes of the prior parts of the model, the *Government action rate* increases or decreases the *Ecological integrity* of a *River basin* based on the implementation of *Sustainable* or Non *sustainable actions* (Figs. 59-62).

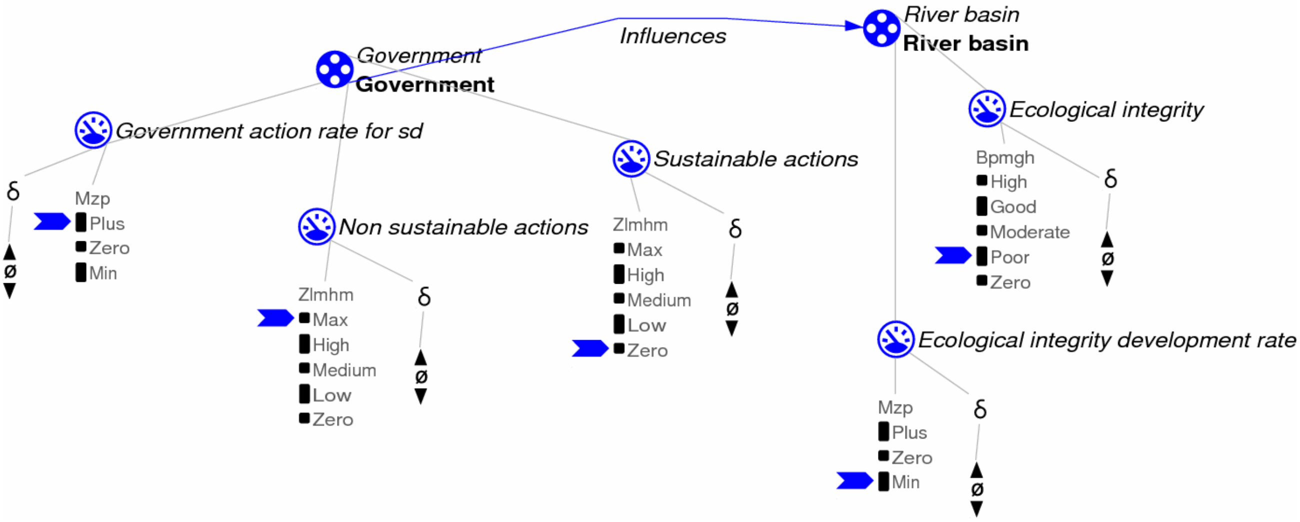


Figure 59: Scenario “Ecological development”.

Table 13: Simulation summary “Ecological development”.

Scenario name	“Ecological development”
Full simulation	20 states
Initial states	[1]
End states	[3, 4, 7, 18, 19]
Relevant behaviour paths	[1, 2, 5, 9, 11, 17, 18] and
Behaviour description	*Non sustainable actions* are at maximum at the beginning of the simulation, but are constantly decreasing triggered by the government action rate, which is set to plus in the beginning. The *Government action rate* links this simulation to the scenarios described before. The *Ecological integrity development rate* reacts to the changed relation between *Sustainable* and *Non sustainable actions* and influences the *Ecological integrity*, which first decreases, then stabilizing and then increasing; the behaviour of the *Ecological integrity* (reaching its maximum after *Sustainable actions* remain at a maximum level for several modelling steps) can be interpreted as the time that is necessary for an ecosystem to recover from disturbance, although behaviour described as *Sustainable actions* has already changed.

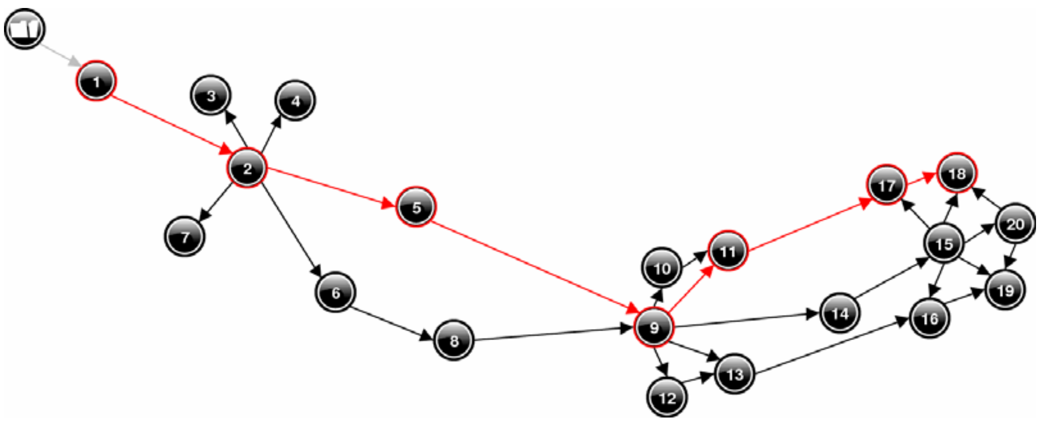


Figure 60: Behaviour graph obtained in a simulation of the scenario “What affects the quality of sustainability plans”.

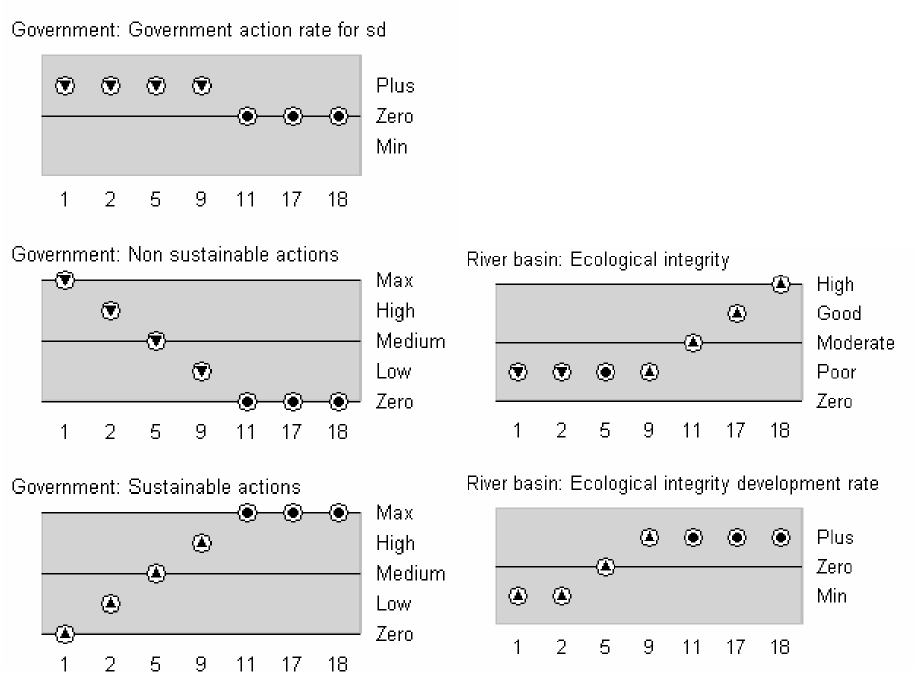


Figure 61: Value history diagrams of the quantities in the described behaviour path of the simulation of the scenario "What affects the quality of sustainability plans".

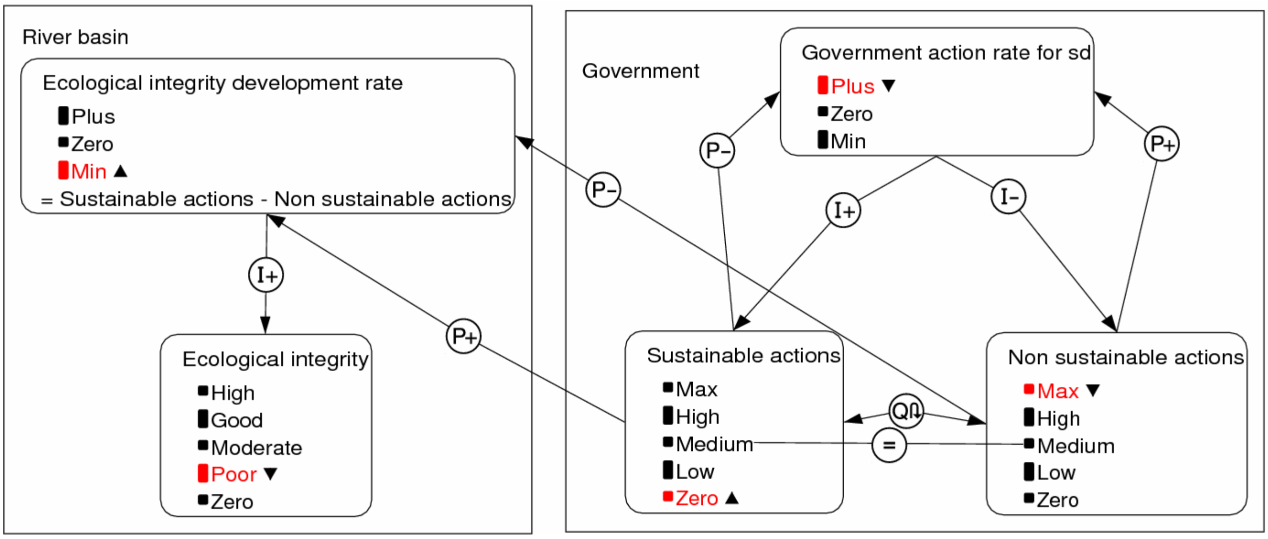


Figure 62: Detailed representation of the causal model in state 1 of the simulation of the scenario "What affects the quality of sustainability plans".

2.7.2.2 "Human well being development"

This scenario represents the second end-point of the whole process described within the other sub-models. Based on different outcomes or the prior parts of the model, the *Government action rate* increases or decreases the *Human well being* of a *Community* living in a *River basin*, based on the implementation of *Sustainable* or *Non sustainable actions* (Figs. 63-66).

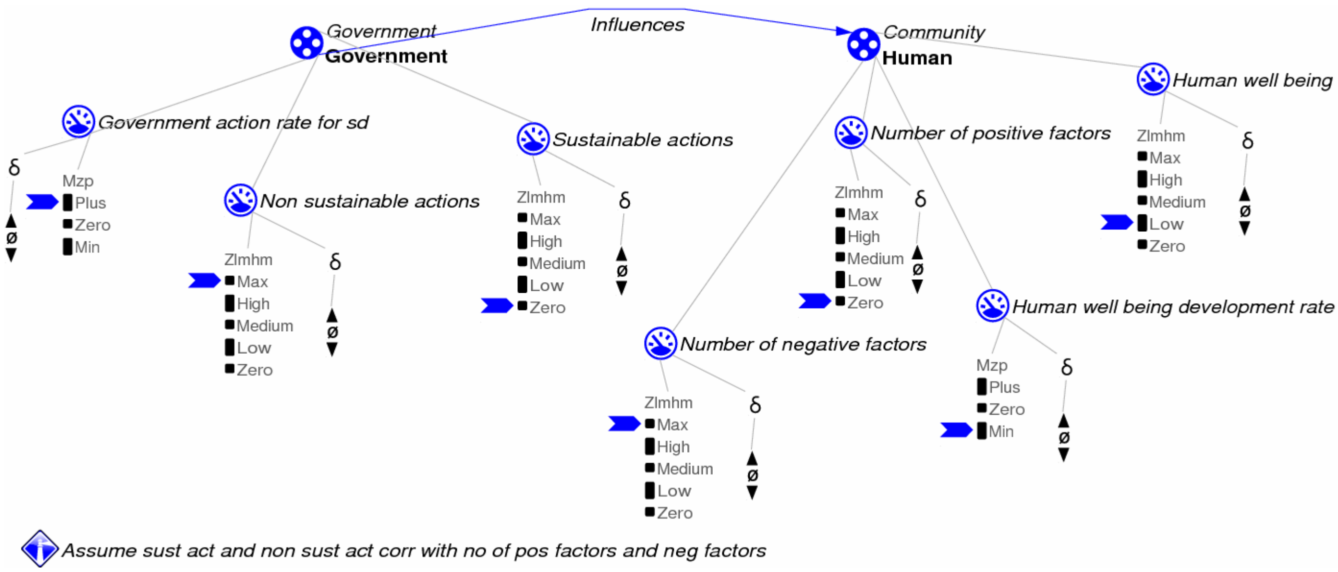


Figure 63: Scenario "Human well being development".

Table 14: Simulation summary "Human well being development".

Scenario name	"Human well being development"
Full simulation	17 states
Initial states	[1]
End states	[3, 5, 15, 16]
Relevant behaviour paths	[1, 2, 4, 6, 8, 14, 15]
Behaviour description	The *Human well being development rate* is calculated by the relationship between *Number of positive and negative factors* and influences the *Human well being*, which first decreases, then stabilizes and then increases; the behaviour of the *Human well being* (reaching its maximum after *Number of positive factors* remain at a maximum level for several modelling steps) can be interpreted as the time that is necessary for a human community to recover from bad circumstances, although the situation has already changed.

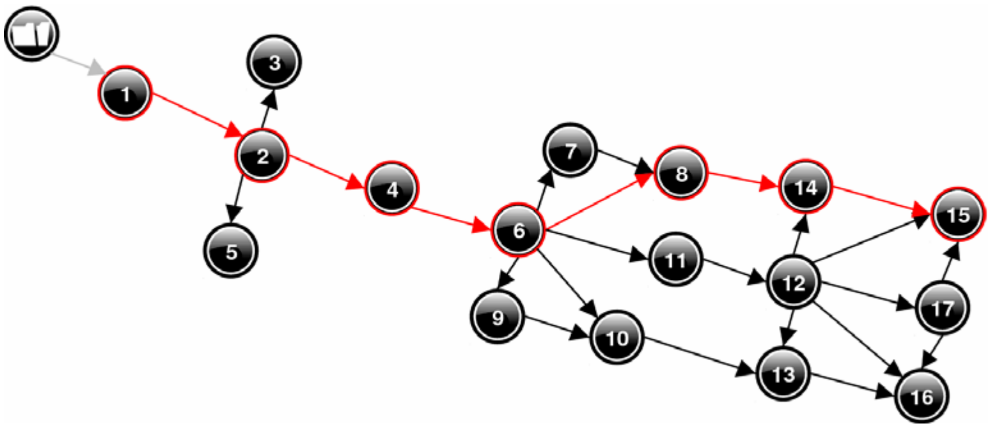


Figure 64: Behaviour graph obtained in a simulation of the scenario "Human well being development".

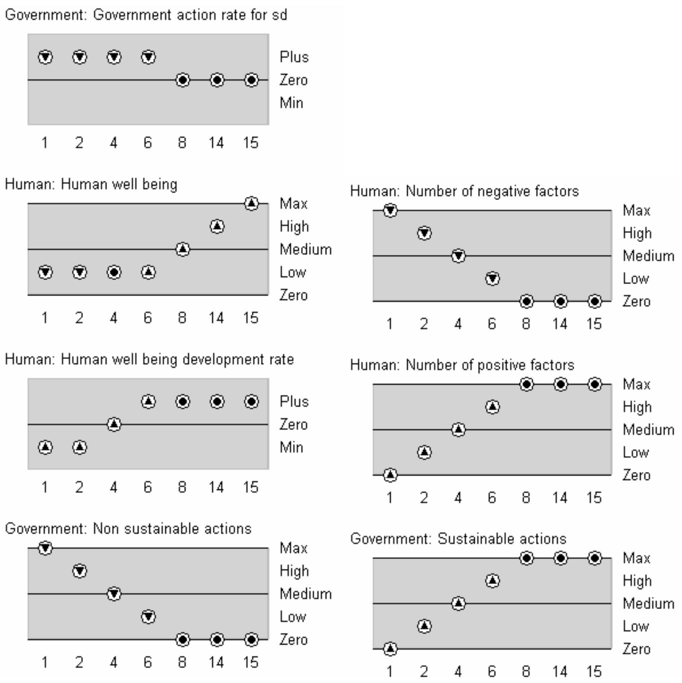


Figure 65: Value history diagrams of the quantities in the described behaviour path of the simulation of the scenario “Human well being development”.

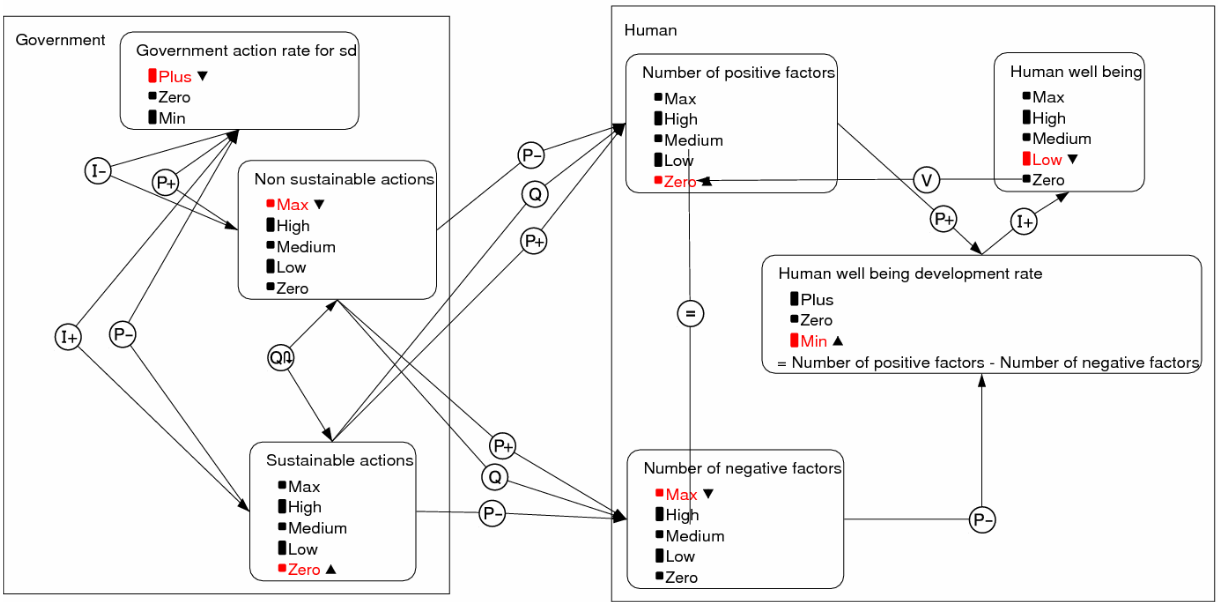


Figure 66: Detailed representation of the causal model in state 1 of the simulation of the scenario “Human well being development”.

3 Model B – "Water abstraction and fish"

Model B explores important problems related to hydropower use in the Kamp valley and its effect on fish. Additionally the aspect of energy production, consumed energy and energy sold is modelled together with stakeholder satisfaction to represent the causal basis for hydropower use by stakeholders and the driving principle behind the tendency of increasing the amount of abstracted water to increase income and stakeholder satisfaction.

There are mainly two ways of influencing a river by hydropower use: (1) water abstraction and the creation of a residual or minimum flow stretch with the related effects to the physical environment like loss of water, loss of flow velocity reduction of depth and an increase of water temperature and (2) the storage of water in a reservoir and a constant or peaking release of water from hypolimnetic parts of the reservoir which leads to decreased temperatures below the reservoir favouring cold water species and repressing the reproduction of warmwater species; if the water is on the one hand released at a constant rate this destroys the natural flow regime of a river, if released in a peaking mode ("hydropeaking") it affects fish due to he frequent changes of habitat conditions. Therefore model B focuses on the one hand the exploration of the two ways of hydropower use (direct use via a hydropower plant and abstraction to fill a reservoir with subsequent energy production). Additionally representations are developed that describe the effects of a reduced amount of water in the river (reduced flow velocity and increased temperature) and its effects on the fish fauna; both negative and positive effects of the changed physical environment on fish (favouring fish due to temperature increase or suppressing them; favouring fish with low requirements to flow velocity, the so called indifferent species, or suppressing species with high flow velocity needs, the so called rheophilous species) are captured in model fragments. The developed representations allow for a comprehensive analysis of the different effects of the different modes of hydropower production on sensitive guilds of the river type specific fish community of the river Kamp.

3.1 Entities, configurations and quantities

The entities are defined according the main perspectives we wanted to represent in the model B: *Energy source (Hydropower plant), Fish (Flow velocity sensitive fish, Temperature sensitive fish), Stakeholder (private owner), Water* and *water body (Reservoir, River)* (Fig. 67).

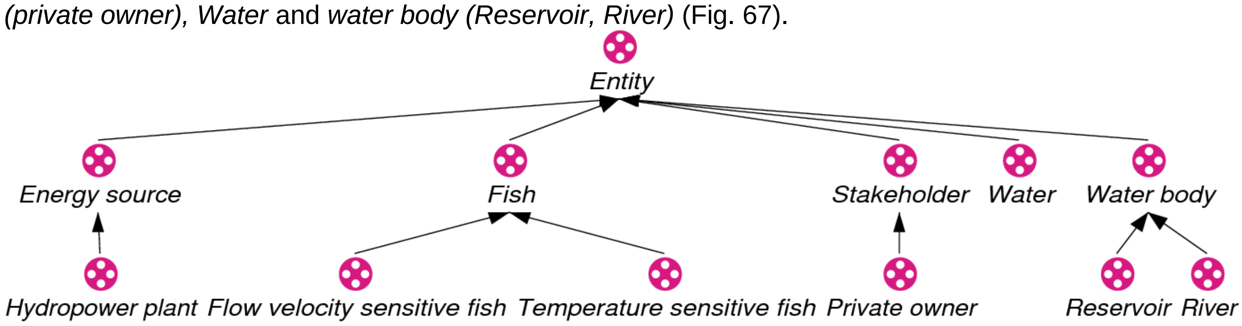


Figure 67: Entity hierarchy for model B describing hydropower use in the Kamp valley and its effect on fish.

3.2 Configurations

The above mentioned entities are related among themselves by means of *configurations*. Entities and configurations create the structure of the system being modelled. Fig. 68 shows the full picture of model B.

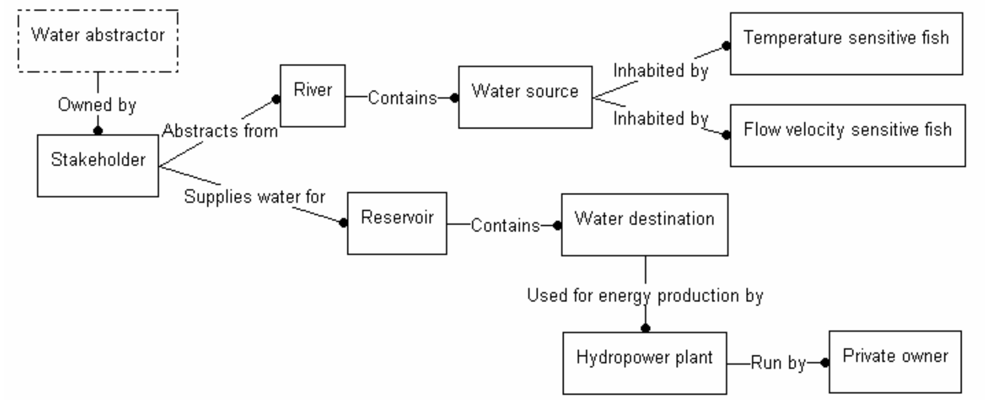


Figure 68: Entities and configurations used to define the system structure of the "Water abstraction - fish" model.

3.3 Quantities and Quantity spaces

The quantities used in the Kamp valley hydropower use and fish model (model B) and their respective sets of possible qualitative values (the quantity spaces) are presented in Tab. 15. Rates are treated separately from other quantities and remarks are given to further describe the quantities. The quantity spaces are identified by labels that read as follows: zp = {zero, plus}; mzp = { minus, zero, plus}; zlmh = {zero, low, medium, high} and zlmhm = {zero, low, medium, high, maximum}.

Table 15: Quantities and quantity spaces used in the "Community fear" sub-model.

Quantity	Quantity space	Remarks
	Rates of processes	
Energy growth rate	mzp	Represents the relationship of produced and consumed energy influencing extra energy, that can be sold.
Population growth rate	mzp	This rate influences the number of fish via indirectly representing the processes of birth and mortality.
Water abstraction rate	zp	This rate is used to represent the water abstraction from the river and the water supply to the reservoir.
Water net flow	mzp	Rate describing the relationship of water flowing in and water flowing out describing the amount.
	Other quantities	
Abstracted water	zlmhm	Refers to he amount of abstracted water that also is supplied to the reservoir.
Amount of water	zlmhm	Refers to the amount of water in the river.
Water flowing in	zlmhm	Refers to the water that flows into a specific river section.
Water flowing out	zlmhm	Refers to the water that flows out of a specific river section.
Generated energy	zlmhm	Refers to the total energy created by hydropower production.
Consumed energy	zlmhm	Refers to the energy that is consumed by the stakeholder.
Extra energy	zlmhm	Refers to the amount of energy that is calculated by the total amount of energy produced minus the consumed energy and is available for being sold.
Profit	zlmhm	Refers to the money earned by extra energy.
Satisfaction	zlmhm	Refers to the satisfaction of the stakeholder when the profit is increasing.
Flow velocity	zlmhm	Refers to the flow velocity of a river to which the type specific species are adopted and that is changed due to water abstraction.
Water depth	zlmhm	Refers to an important habitat characteristic for mainly larger fish that is changed due to water abstraction.
Water temperature	zlmhm	Refers to the water temperature of a river to which the type specific species are adopted and that is changed due to water abstraction.
Number of	zsml	This quantity is used to represent the population size of the modelled guilds.

3.4 Model fragments

The model B consists of 41 model fragments, 30 of them being static, nine of them being processes and two of them being agents.

3.4.1 “River water configuration”

This model fragments represent a river that contains water with two potential situations: the *Amount of water is greater than zero* or the *Amount of water is equal zero* (Fig. 69).

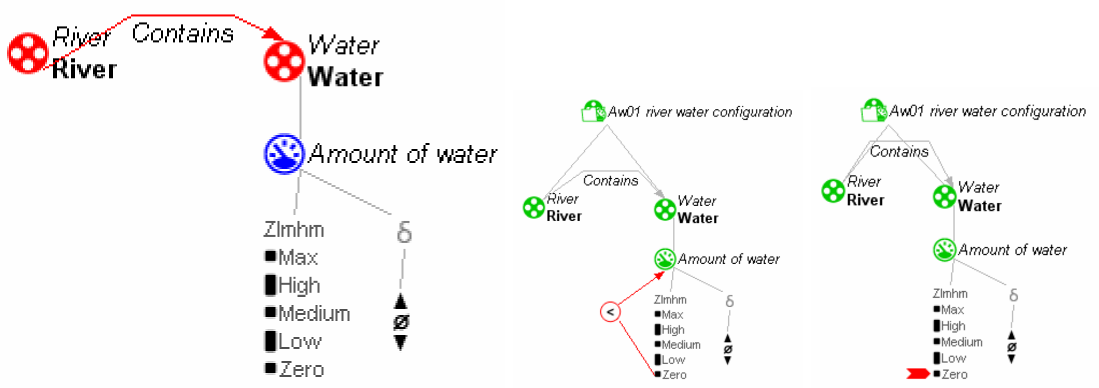


Figure 69: Static model fragment “River water configuration”.

3.4.2 “Reservoir water configuration”

The *Reservoir* is filled with *Abstracted water*; two situations are pre-defined: *Abstracted water greater than zero*, and *Abstracted water equal zero* (Fig. 70).

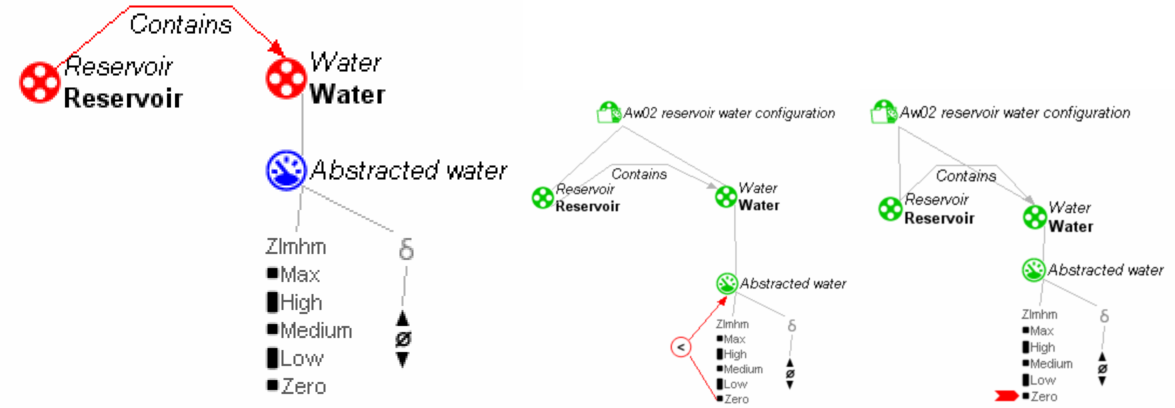


Figure 70: Static model fragment Reservoir water configuration”.

3.4.3 "Water flow in river configuration"

This MF captures the idea that he amount of water in a river section can be represented as the *Amount of water flowing in* and the *Amount of water flowing out* (Fig. 71).

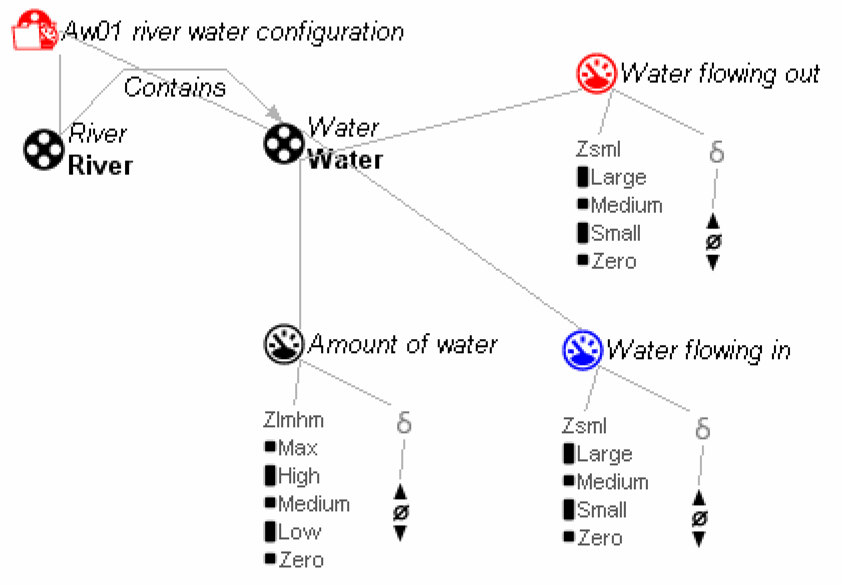


Figure 71: Static model fragment "Water flow in river configuration".

3.4.3.1 "Assume flow in medium and steady"

The assumption "Flow in medium and steady" is implemented in the static model fragment "Water flow in river configuration" (Fig. 72).

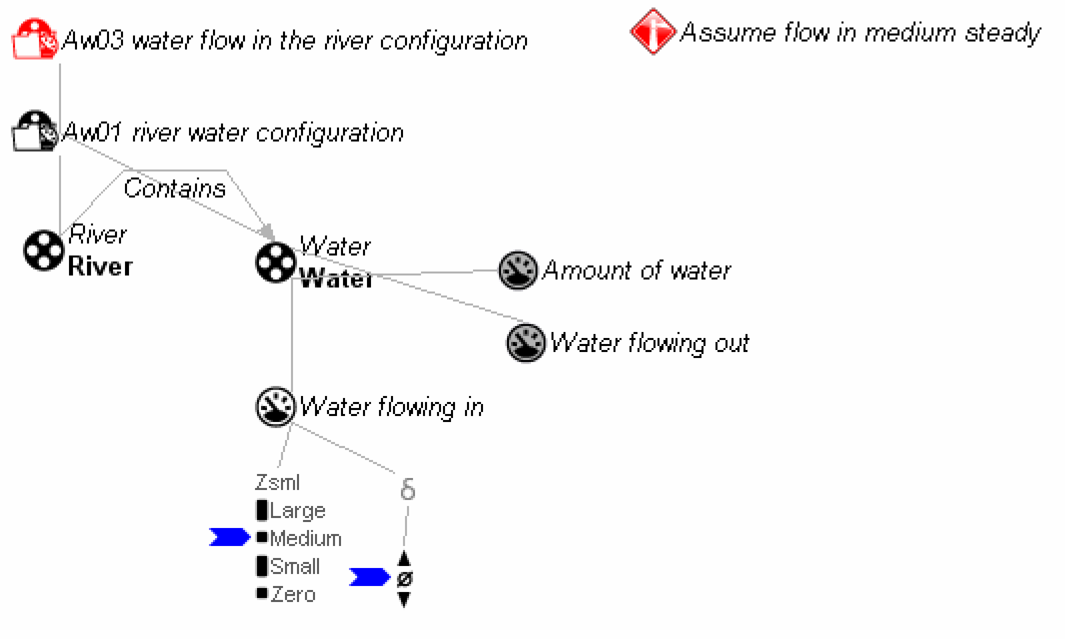


Figure 72: Static model fragment "Assume flow in medium and steady".

3.4.3.2 “Assume both flow in and flow out medium and steady”

The assumption “Flow in and out medium and steady” is implemented in the static model fragment “Water flow in river configuration” (Fig. 73).

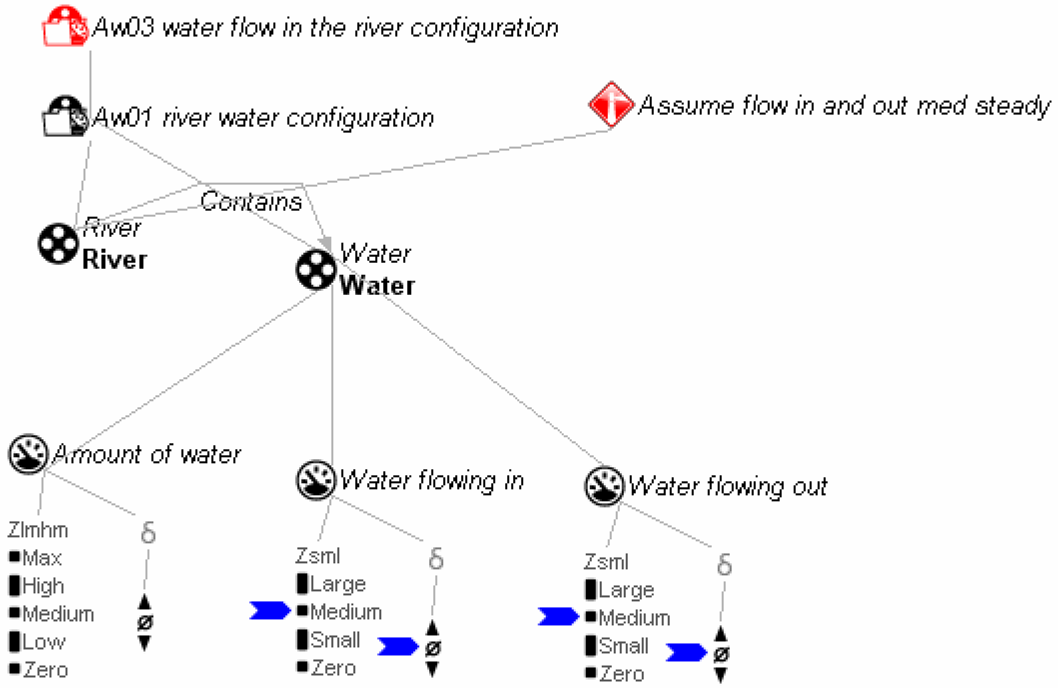


Figure 73: Static model fragment 3.4.3.2 “Assume both flow in and flow out medium and steady”.

3.4.4 “Stakeholder abstracts water from river configuration”

This model fragment represents the configuration of a *Stakeholder*, who abstracts *Water* from a *River* that contains an *Amount of water* (Fig. 74).

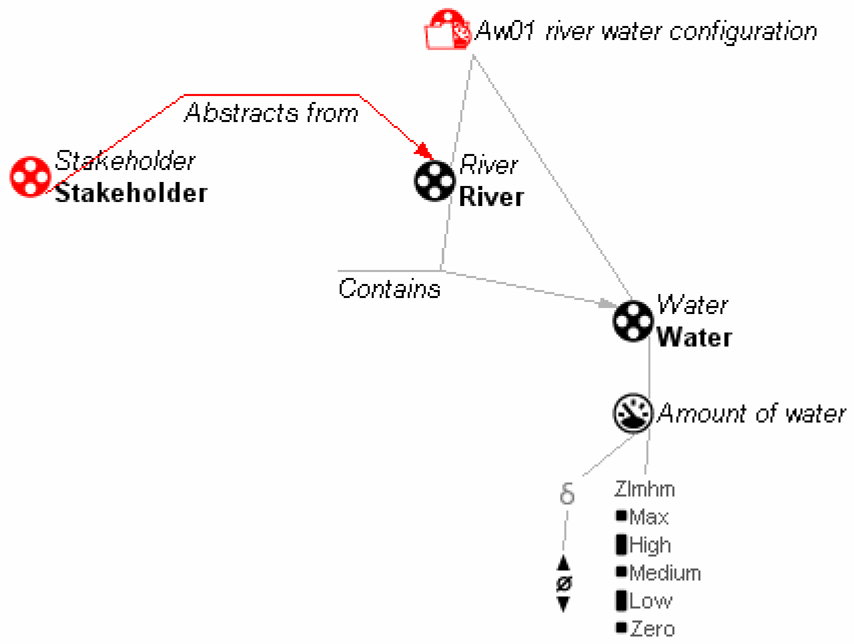


Figure 74: Static model fragment “Stakeholder abstracts water from river configuration”.

3.4.5 "Stakeholder supplies water to reservoir configuration"

To capture the more advanced idea of water being abstracted and supplied for a *Reservoir,* the following configuration was developed (Fig.75).

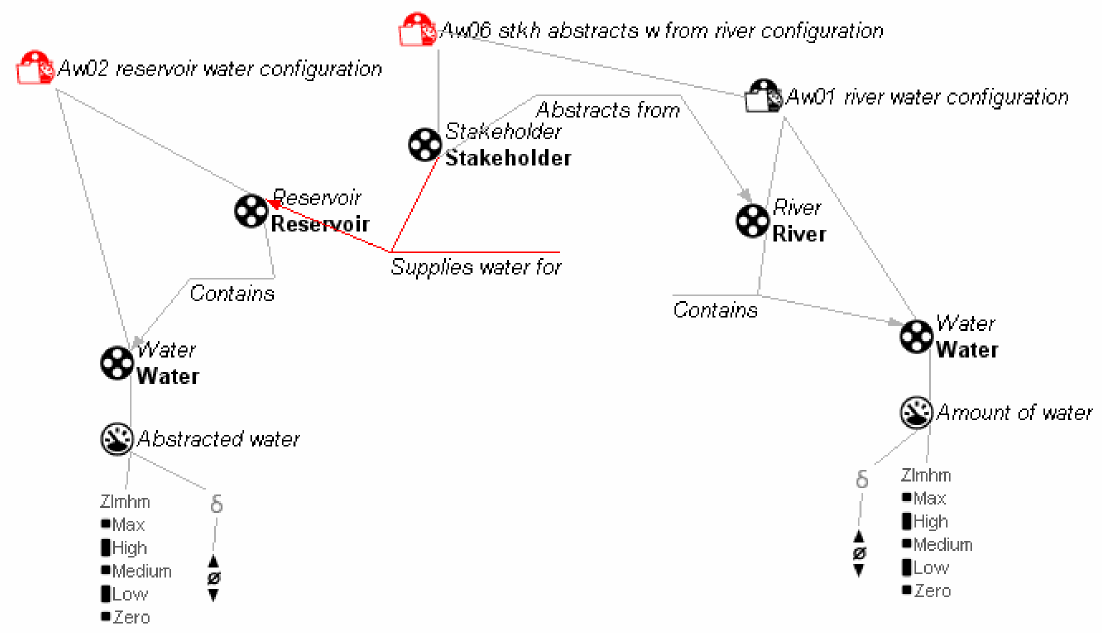


Figure 75: Static model fragment "Stakeholder supplies water to reservoir configuration".

3.4.5.1 "Assume abstracted water and amount of water in the river inverse corresponding"

The assumption "Assume abstracted water and amount of water in the river inverse corresponding" is implemented in the model fragment "Stakeholder supplies water to reservoir configuration" (Fig. 76).

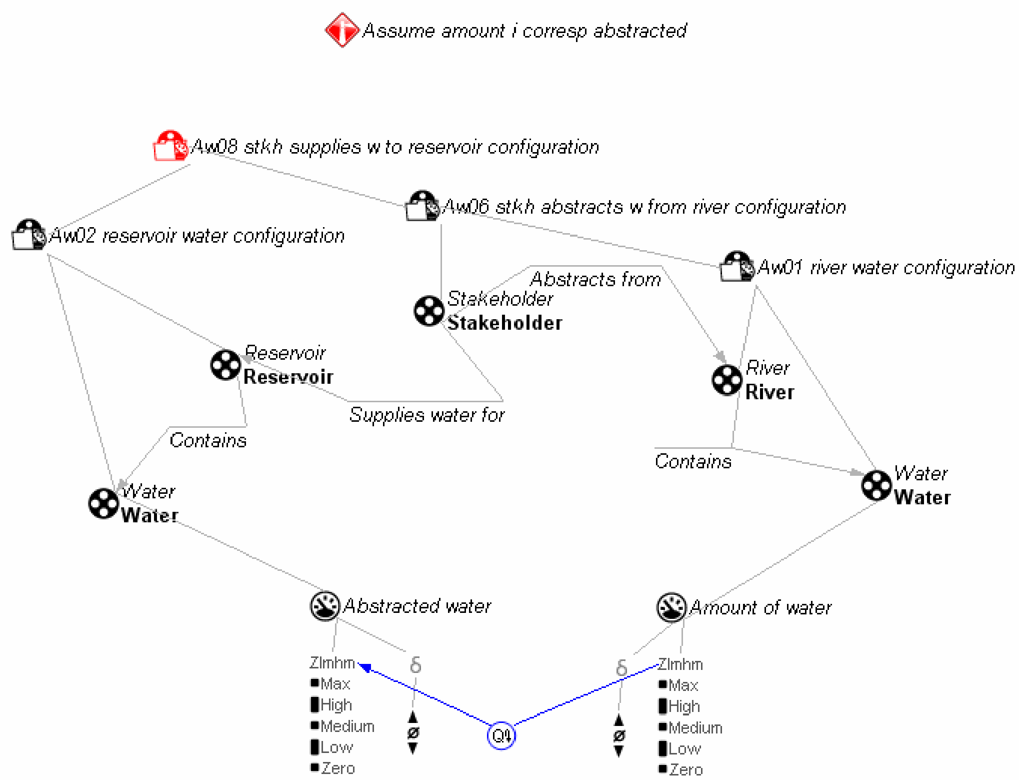


Figure 76: Static model fragment "Assume abstracted and supplied water inverse corresponding".

3.4.6 "River physical factors configuration"

To represent the relationship between the *Amount of water in the river* and the physical factors (*Water temperature, Flow velocity* and *Water depth*) the MF "River physical factors configuration" was developed, with *Water temperature* being inverse corresponding and *Water depth* and *Flow velocity* being direct corresponding to the *Amount of water* (Fig. 77).

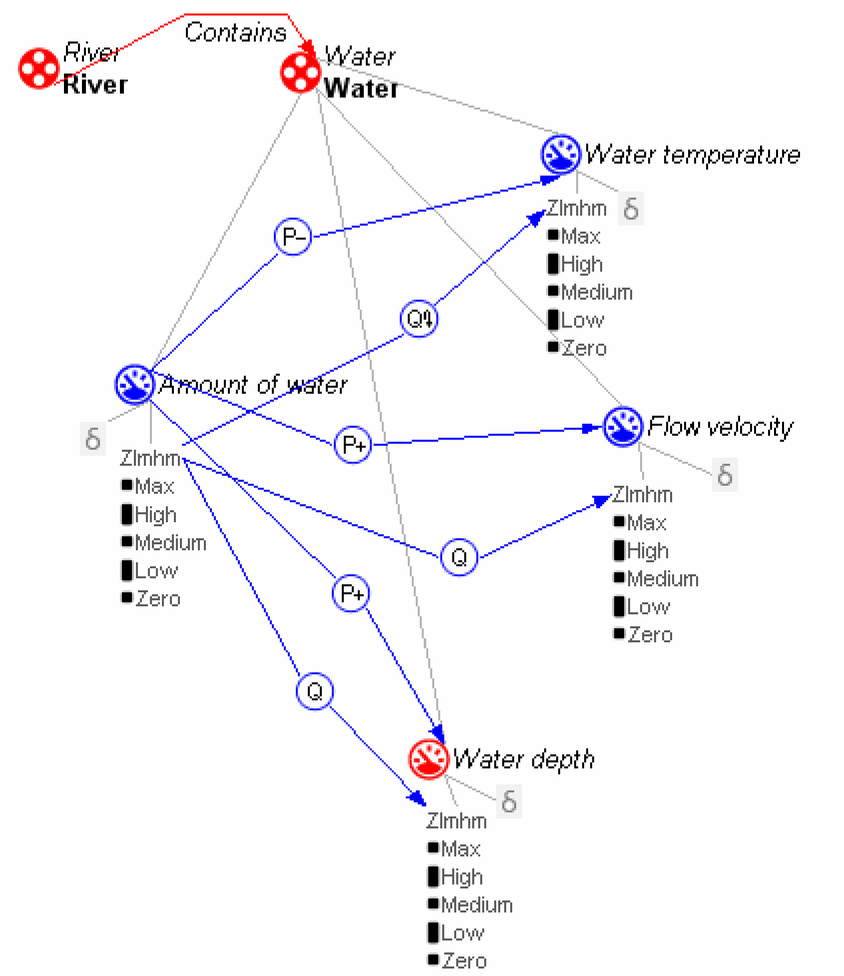


Figure 77: Static model fragment "River physical factors configuration".

3.4.7 "Fish configuration"

The Fish populations are characterized by the *Number of*, with two situations being considered: *Number of fish greater zero* and *Number of fish equal zero* (Fig. 78).

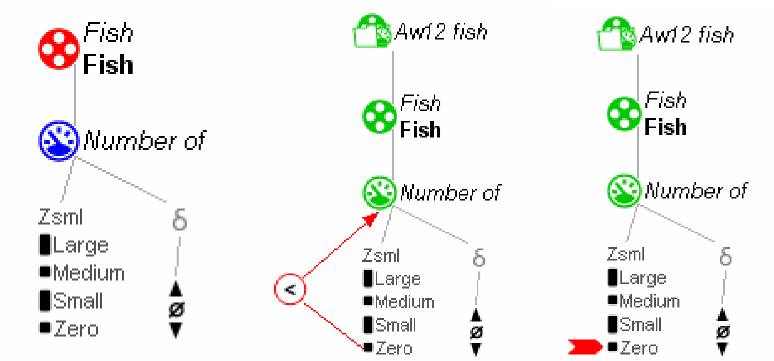


Figure 78: Static model fragment "Fish configuration".

3.4.8 "Temperature sensitive fish configuration"

Fig. 79 shows the configuration of a *Temperature sensitive fish* population.

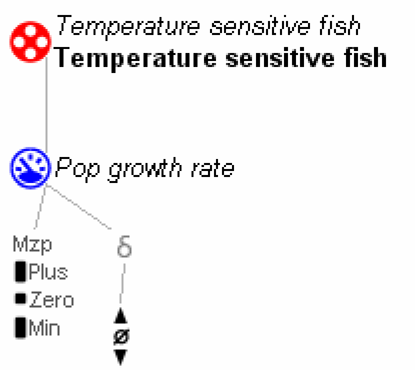


Figure 79: Static model fragment "Temperature sensitive fish configuration".

3.4.9 "Water abstraction and positive effect of temperature on fish"

Water abstraction might lead to increased *Water temperatures* that might favor species adapted to higher temperatures leading to an increased *Number of fish*; this situation is represented in the MF "Water abstraction and positive effect of temperature on fish" (Fig. 80).

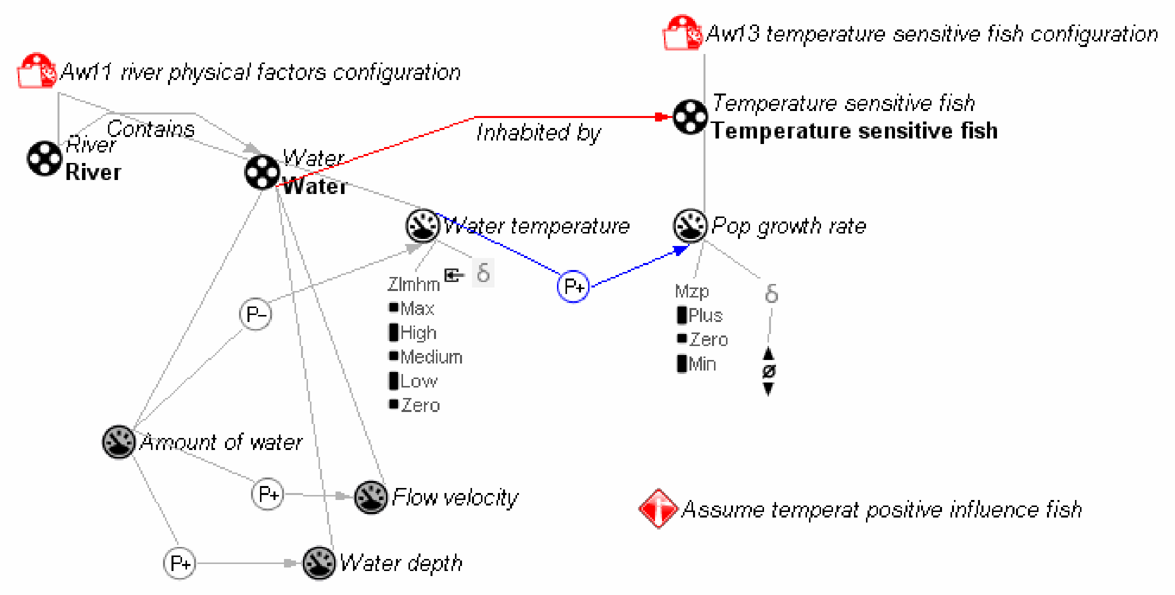


Figure 80: Static model fragment "Water abstraction and positive effect of temperature on fish".

3.4.10 “Water abstraction and negative effect of temperature on fish”

Water abstraction might lead to increased *Water temperatures* that might suppress species adapted to lower temperatures leading to a decreased *Number of fish*; this situation is represented in the MF “Water abstraction and negative effect of temperature on fish” (Fig. 80).

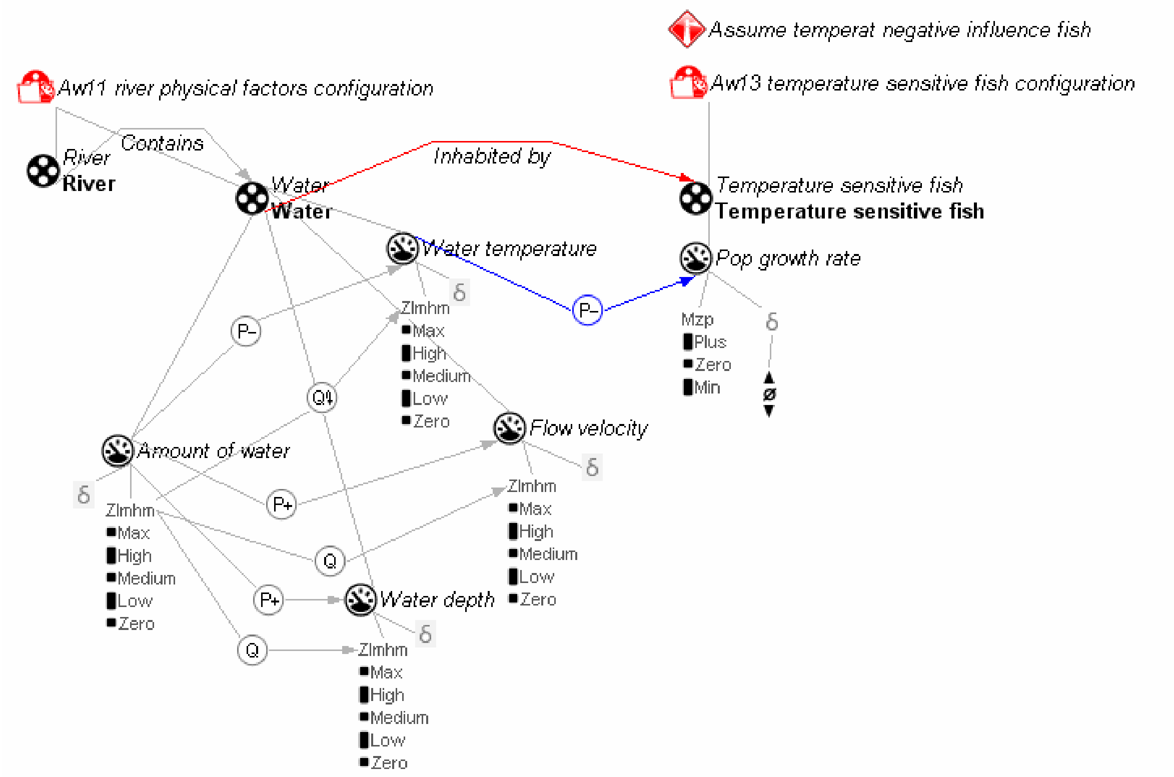


Figure 81: Static model fragment “Water abstraction and negative effect of temperature on fish”.

3.4.11 “Flow velocity sensitive fish configuration”

Fig. 82 shows the configuration of *Flow velocity sensitive fish* population.

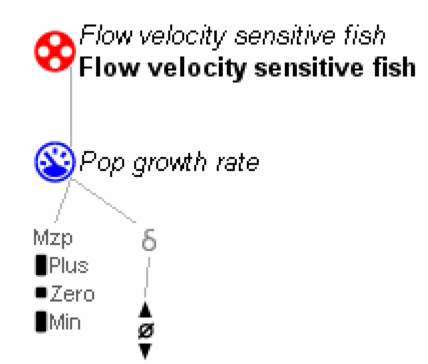


Figure 82: Static model fragment “Temperature sensitive fish configuration”.

3.4.12 “Water abstraction and positive effect of flow velocity on fish”

Water abstraction often leads to decreased flow velocities; in the river Kamp the guild of rheophilous fish especially is impacted by a decreased *Amount of water* and therefore decreased *Flow velocities*; this situation, where increased flow velocities support the guild of flow velocity dependent fish is represented in the MF “Water abstraction and positive effect of flow velocity on fish” (Fig. 83).

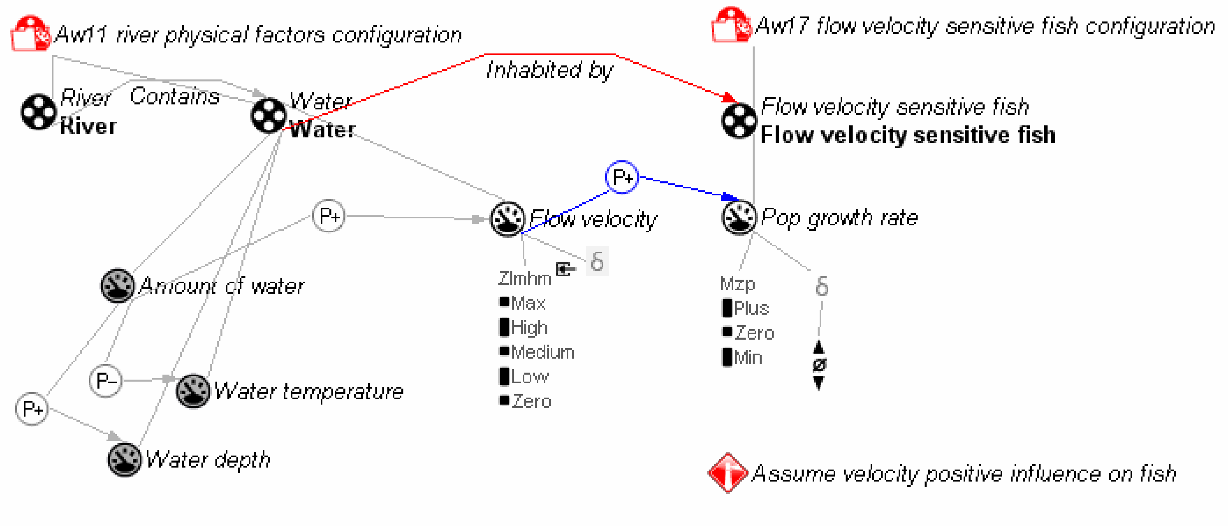


Figure 83: Static model fragment “Water abstraction and positive effect of flow velocity on fish”.

3.4.13 “Water abstraction and negative effect of flow velocity on fish”

Water abstraction often leads to decreased flow velocities; indifferent fish species especially are often supported by a decreased *Amount of water* and therefore decreased *Flow velocities*; this situation, where decreased *Flow velocities* support the guild of flow velocity indifferent fish is represented in the MF “Water abstraction and positive effect of flow velocity on fish” (Fig. 84).

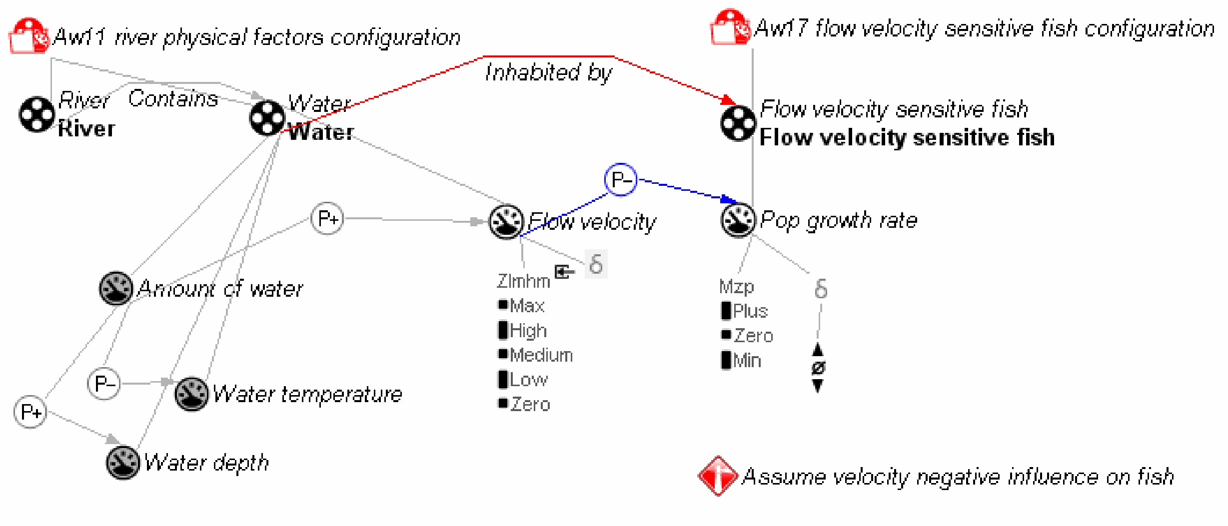


Figure 84: Static model fragment “Water abstraction and negative effect of flow velocity on fish”.

3.4.14 “Extra energy configuration”

Extra energy refers to the energy that can be sold by the stakeholder and is qualitatively calculated by the relationship between *Produced energy* and *Consumed energy* (Fig. 85); two situations are implemented: *Extra energy greater than zero* and *Extra energy equal zero.*

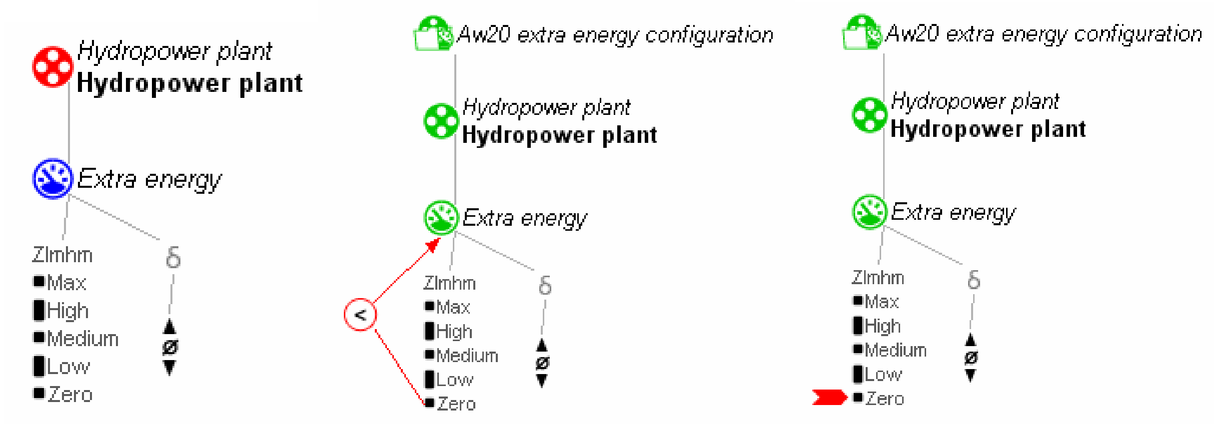


Figure 85: Static model fragment “Extra energy configuration”.

3.4.15 “Hydropower plant configuration”

The static model fragment “Hydropower plant configuration” captures some quantities related to the energy production via a hydropower plant: *Generated energy, Consumed energy* and *Extra energy* (Fig. 86).

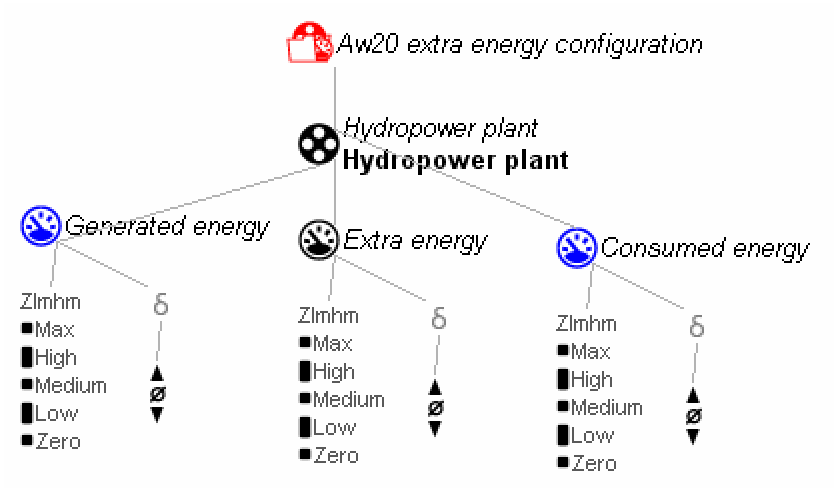


Figure 86: Static model fragment “Hydropower plant configuration”.

3.4.16 “Assume consumed energy medium steady”

The assumption “Consumed energy medium and steady” is implemented in the model fragment “Hydropower plant configuration” (Fig. 87).

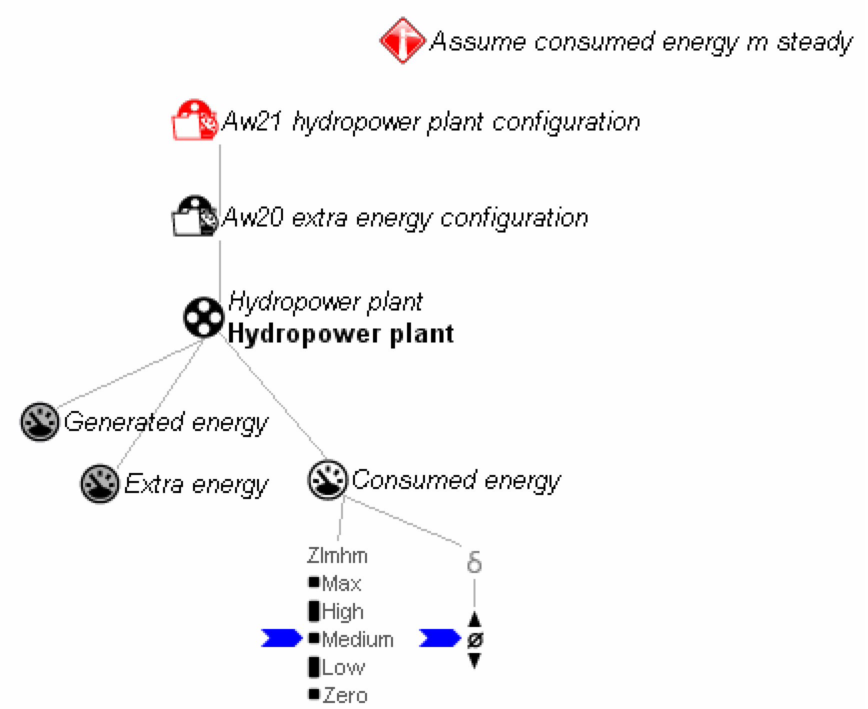


Figure 87: Static model fragment “Assume consumed energy medium steady”.

3.4.17 “Energy generation configuration”

The “Energy generation configuration” describes the *Amount of generated energy* as positively influenced by and direct corresponding to the *Abstracted water* (Fig. 88).

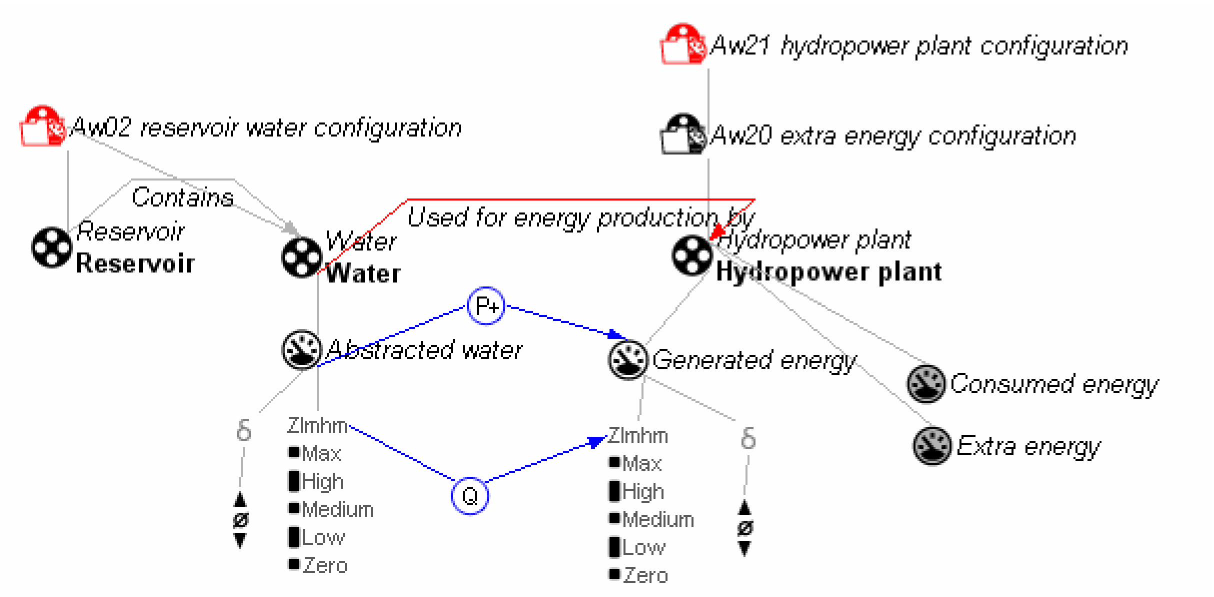


Figure 88: Static model fragment “Energy generation configuration”.

3.4.18 “Private owner configuration”

The “Private owner configuration” considers *Profit* and *Satisfaction* as the most relevant quantities related to the *Private owner* (Fig. 89).

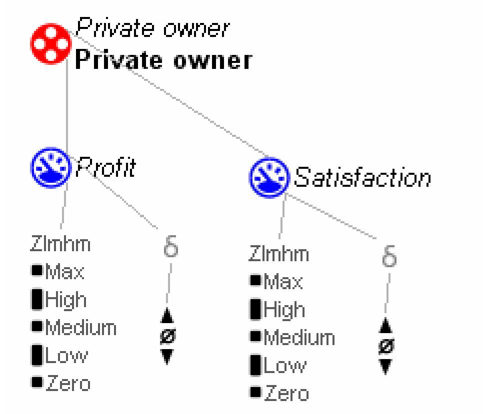


Figure 89: Static model fragment “Private owner configuration”

3.4.19 “Private owner satisfaction configuration”

The “Private owner satisfaction configuration” is mainly seen as depending on the *Extra energy* produced and the *Profit* earned, all quantities are treated as direct corresponding (Fig. 90).

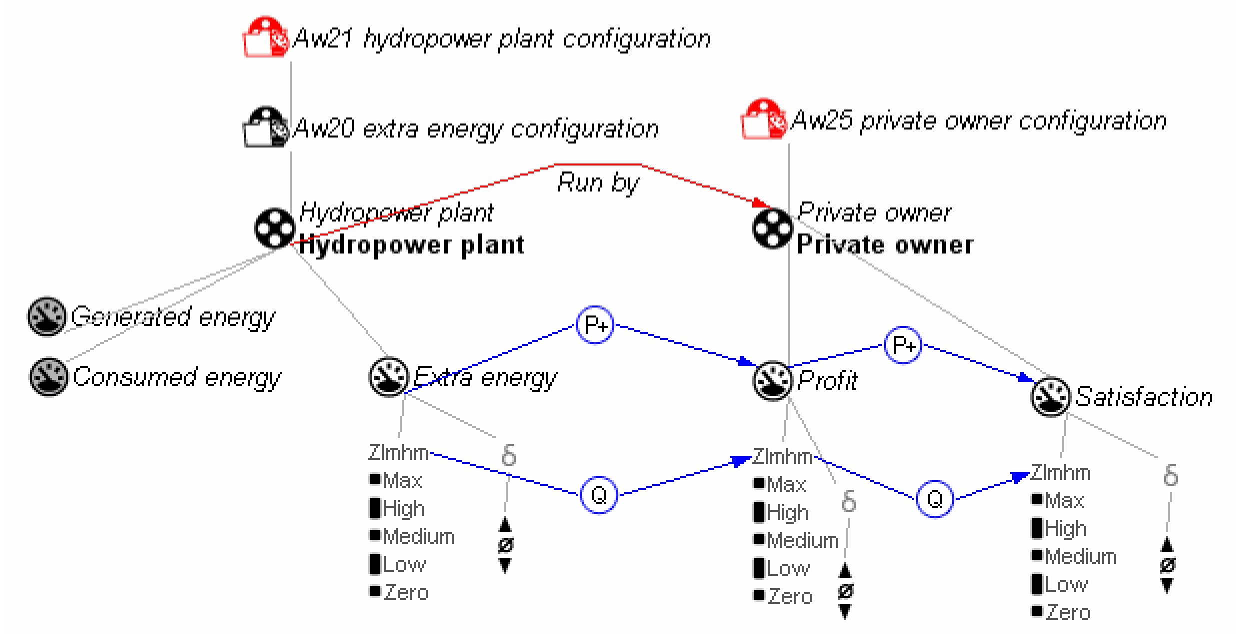


Figure 90: Static model fragment “Private owner satisfaction configuration”.

3.4.20 “Water flow process”

The “Water flow process “ as a process model fragment represents the *Water net flow*, which influences the *Amount of water* being calculated by the difference between *Water flowing in* and *Water flowing out* (Fig. 91).

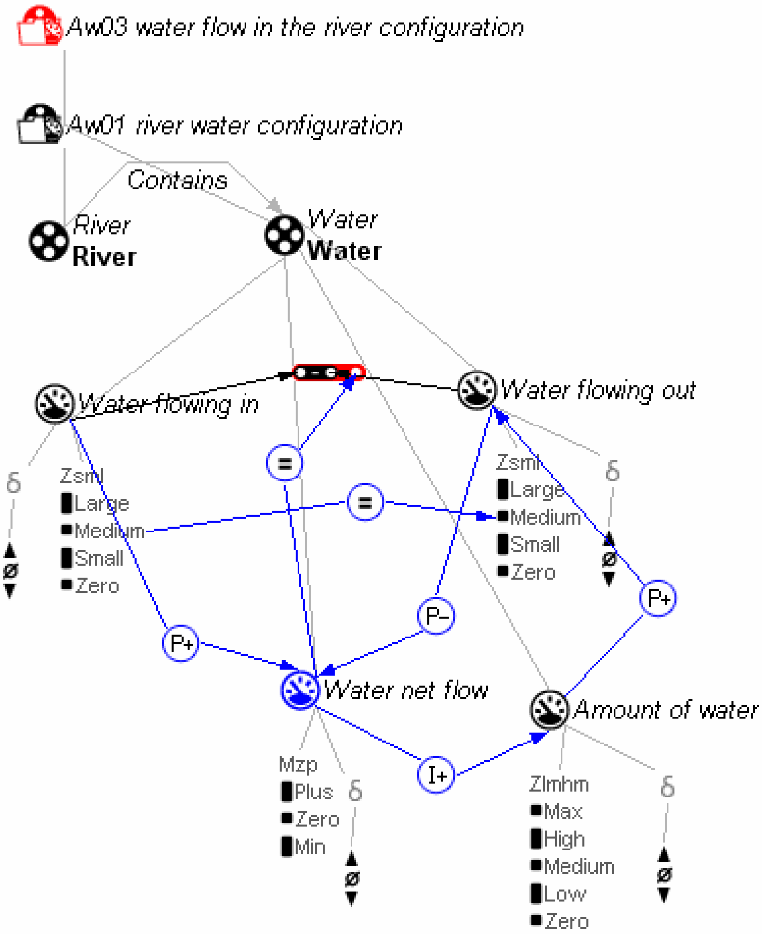


Figure 91: Process model fragment “Water flow process”.

3.4.20.1 "Flow in equals flow out"

The assumption "Flow in equals flow out" is implemented in the process model fragment "Water flow process" (Fig. 92).

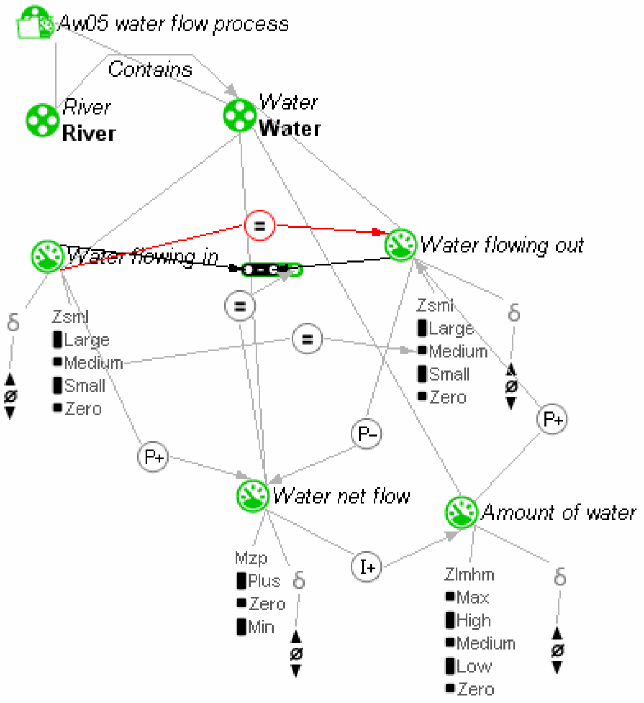


Figure 92: Static model fragment "Assume flow in equals flow out".

3.4.20.2 "Flow in greater flow out"

The assumption "Flow greater flow out" is also implemented in the process model fragment "Water flow process" (Fig. 93).

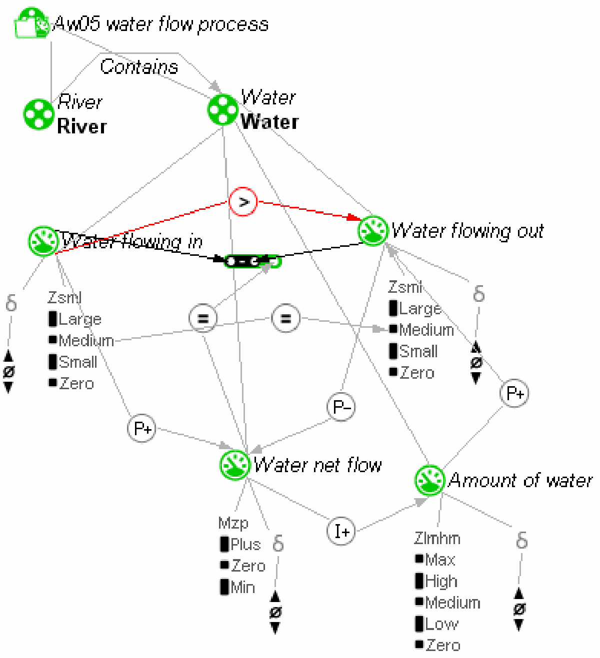


Figure 93: Process model fragment "Flow in greater flow out".

3.4.20.3 "Flow in smaller flow out"

The assumption "Flow in smaller flow out" is also implemented in the process model fragment "Water flow process" (Fig. 94).

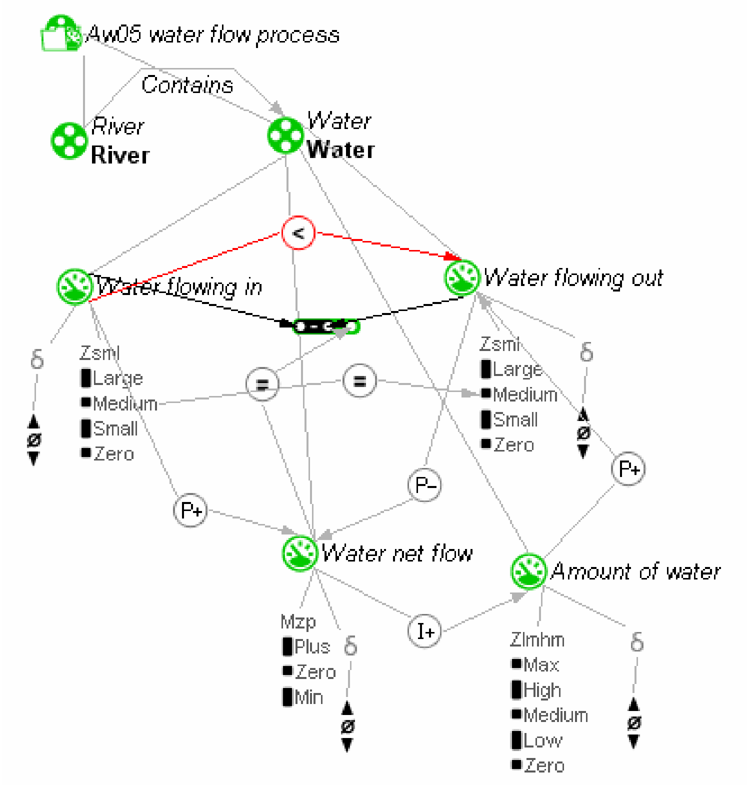


Figure 94: Process model fragment "Flow in smaller low out".

3.4.21 "Fish population growth"

This process model fragment represents the "Fish population growth" process and applies for all kinds of fish (*Temperature sensitive* and *Flow velocity sensitive fish*) (Fig. 95).

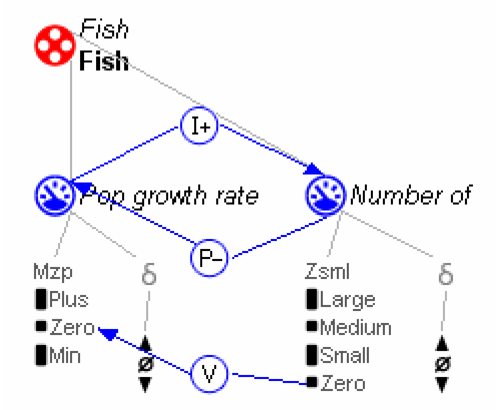


Figure 95: Process model fragment "Fish population growth".

3.4.22 "Energy generation process"

The energy generation process is based on the calculation of the *Energy growth rate* being qualitatively calculated by the relationship between *Generated energy* and *Consumed energy* positively influencing *Extra energy* (Fig. 96).

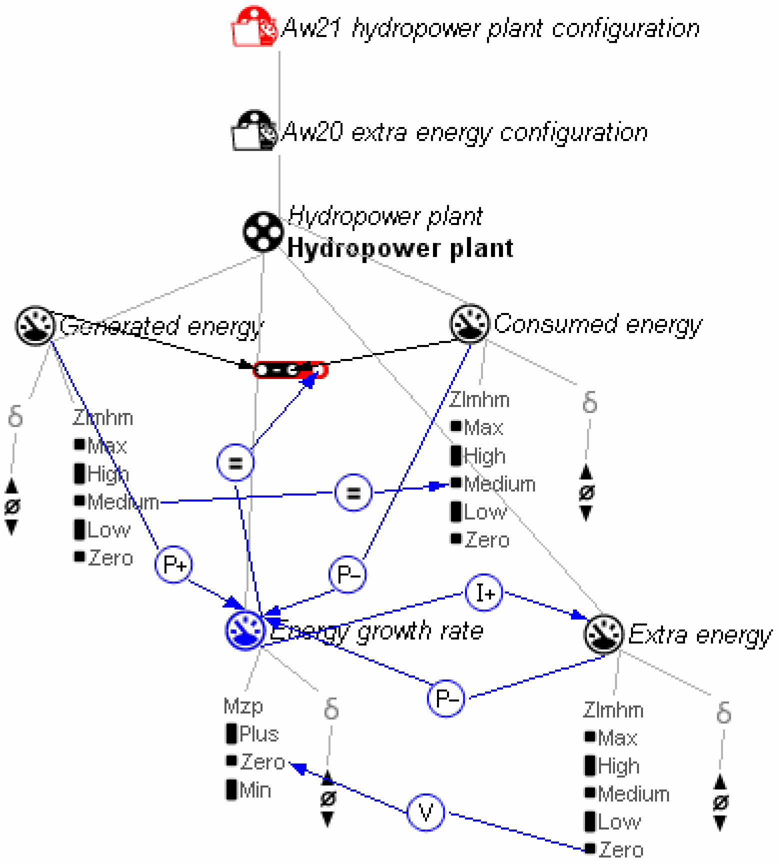


Figure 96: Process model fragment "Energy generation process".

3.4.22.1 "Generated equal consumed"

The assumption "Generated energy equal Consumed energy" is implemented in the process model fragment "Energy generation process" (Fig. 97).

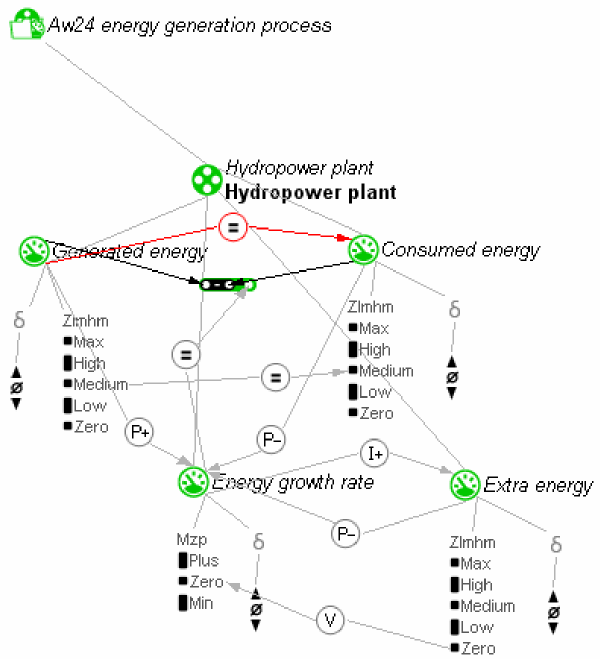


Figure 97: Process model fragment "Generated equal consumed".

3.4.22.2 “Generated greater consumed”

The assumption “Generated energy greater consumed energy” is implemented in the process model fragment “Energy generation process” (Fig. 98).

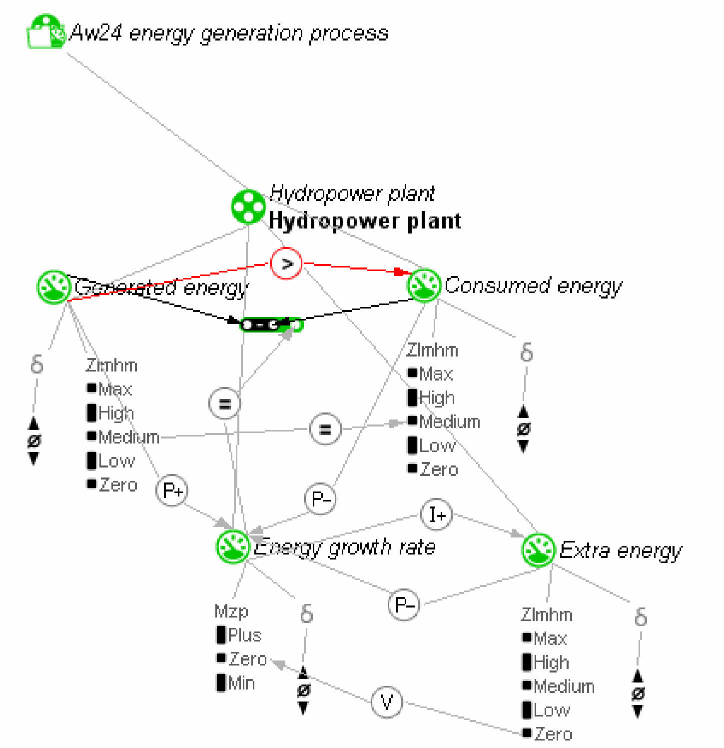


Figure 98: Process model fragment “Generated greater consumed”.

3.4.22.3 “Generated energy smaller consumed”

The assumption “Generated energy smaller consumed energy” is implemented in the process model fragment “Energy generation process” (Fig. 99).

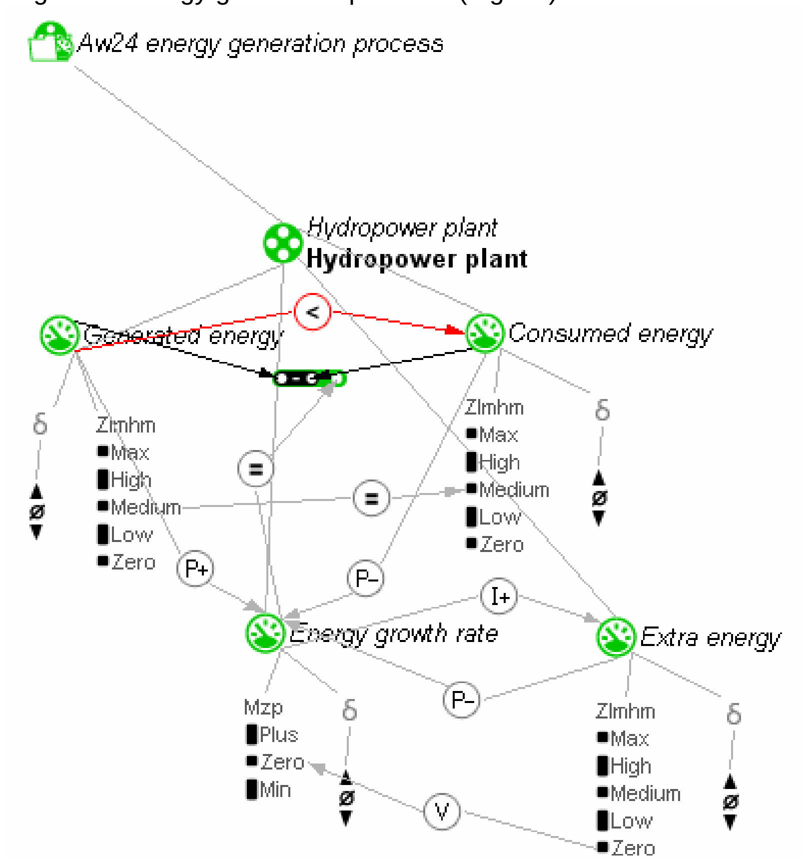


Figure 99: Process model fragment “Generated energy smaller consumed”.

3.4.23 “Agent abstracts water from river”

The agent model fragment “Agent abstracts water from the river” represents a *Water abstractor* owned by a *Stakeholder*, that negatively influences the *Amount of water* in the river; when the *Amount of water* in the river is <Zero>, the *Water abstraction rate* is also set to <Zero> (Fig. 100).

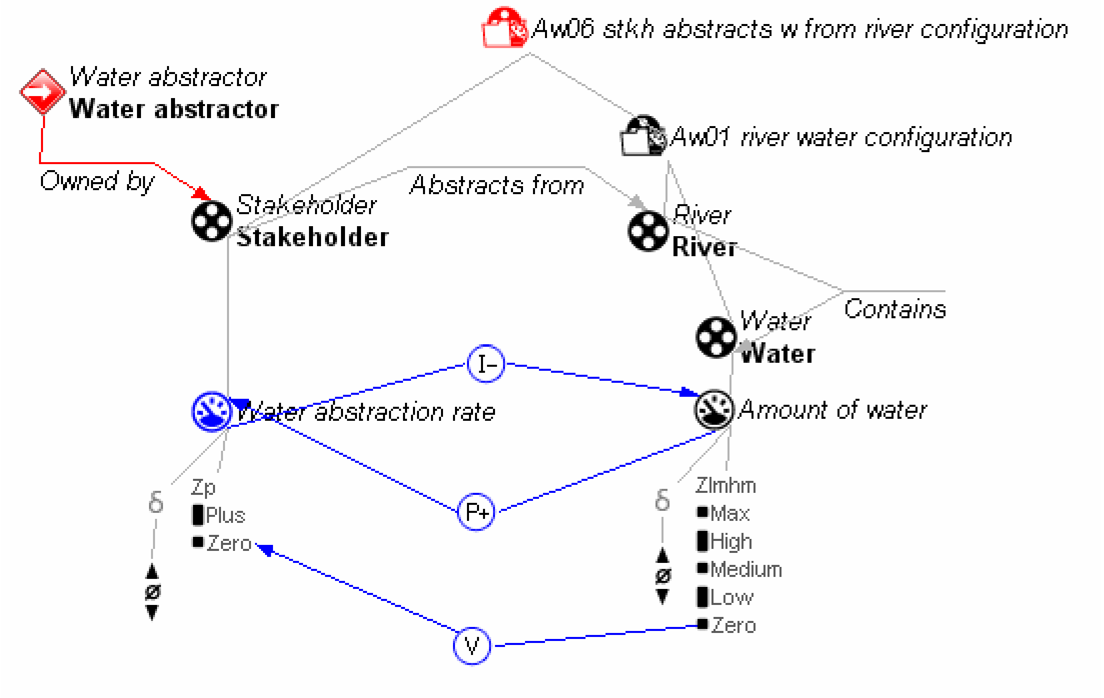


Figure 100: Agent model fragment “Agent abstracts water from river”.

3.4.24 “Agent abstracts and supplies water from river”

The agent model fragment “Agent abstracts and supplies water from the river” represents the abstraction an supply of water that negatively influences the *Amount of water* in the river and at the same time positively influences the *Amount of abstracted water*; when the amount of water in the river is <Zero>, the water abstraction rate is also set to <Zero> (Fig. 101).

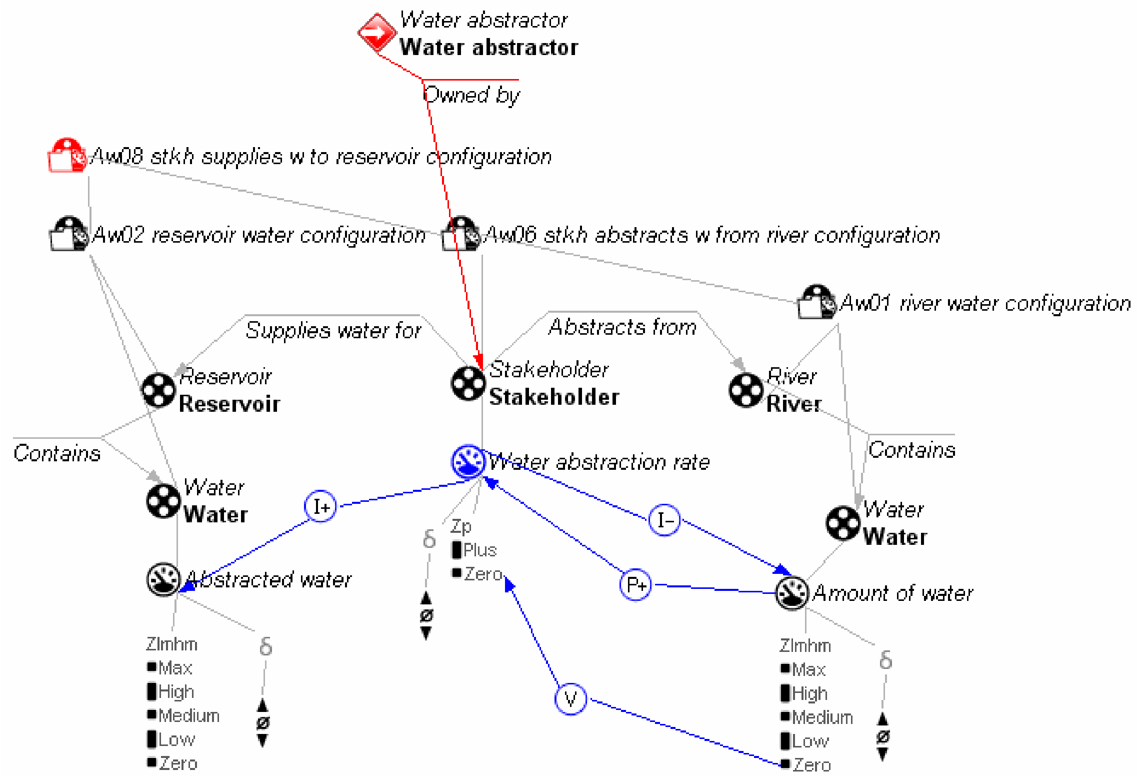


Figure 101: Agent model fragment “Agent abstracts and supplies water from river”.

3.5 Scenarios and simulations

The “Water abstraction and fish” model (Model B) has currently eight scenarios that produce simulation sof increasing complexity. Scenarios 1-3 describe the effects of water abstraction and a reduced amount of water in the river on physical factors and sensitive fish species. Scenarios 4-6 describe the process of water abstraction, supply to a reservoir and the effects of reduced amount of water in the river on physical factors and sensitive fish species. Scenario 7 describes the profit earned by hydropower production based on water abstraction and its effect on stakeholder satisfaction; in this scenario no effects on physical factors and fish are modeled. Scenario 8 presents the most comprehensive view of the water abstraction and fish model.

3.5.1 Scenario 1 “Water abstraction affects physical factors and temperature sensitive fish”

This scenario represents how temperature sensitive fish are affected by water abstraction (Fig. 102).

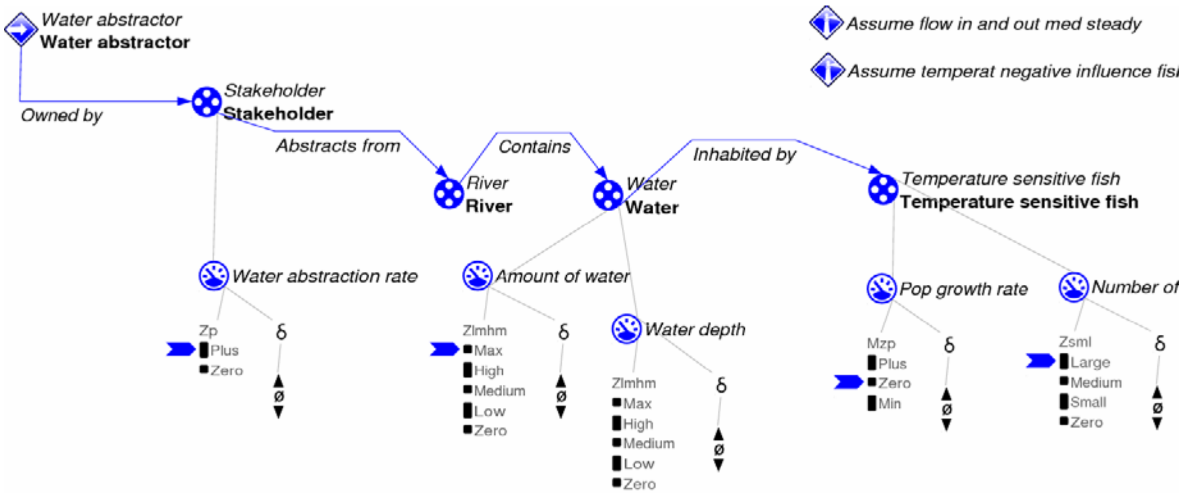


Figure 102: Scenario 1 “Water abstraction affects physical factors and temperature sensitive fish”.

Table 16: Simulation summary of scenario 1 “Water abstraction affects physical factors and temperature sensitive fish”.

Scenario name	“Water abstraction affects physical factors and temperature sensitive fish”
Full simulation	55 states
Initial states	[1]
End states	[22, 26, 27, 30, 31, 32, 33, 34, 35, 40, 41, 42, 43, 48, 49, 50, 51]
Relevant behaviour paths	[1, 2, 12, 21, 42]
Behaviour description	*Agent* abstracts water from *River,* physical factors (*Depth*, *Water temperature* and *Flow velocity*) are influenced and have an effect on fish. *Water depth* and *Flow velocity* are decreasing with decreasing *Amount of water* in the *River* and *Water temperature* is increasing, with negative consequences on the *Population growth rate* of fish sensitive to increased temperatures.

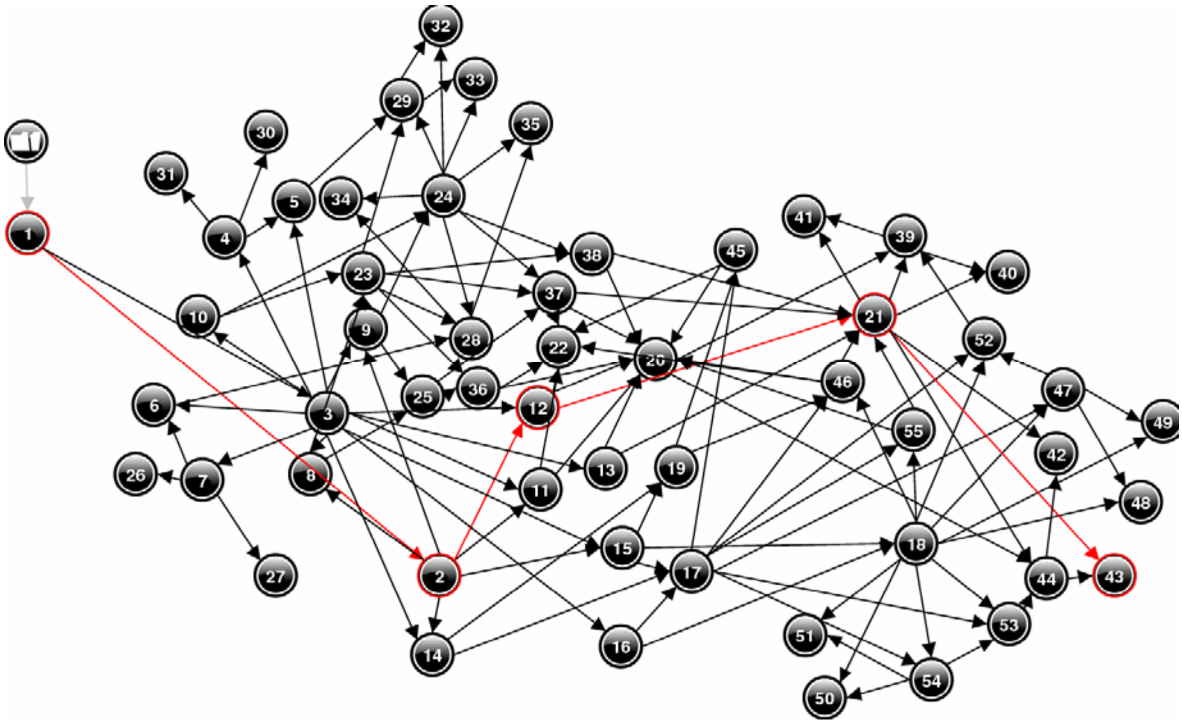


Figure 103: Behaviour graph obtained in a simulation of the scenario 1 “Water abstraction affects physical factors and temperature sensitive fish”.

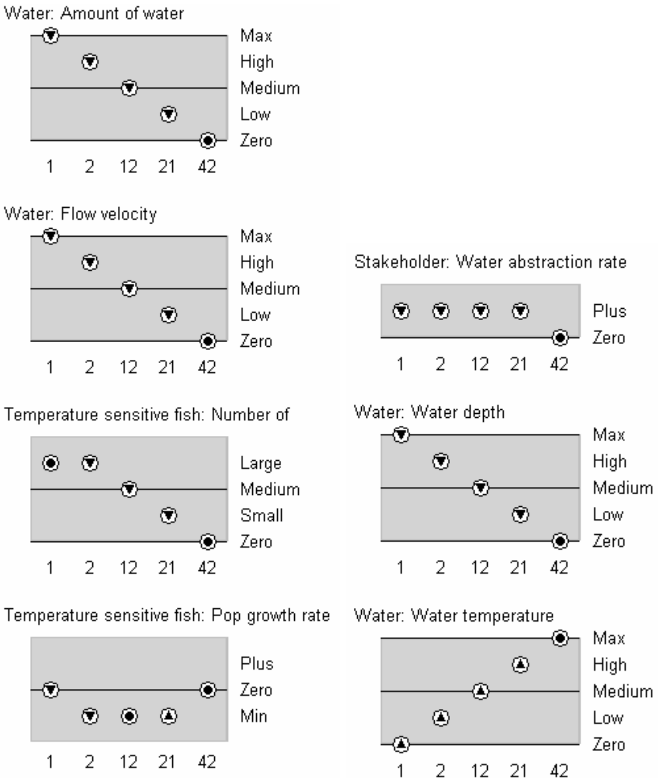


Figure 104: Value history diagrams of the quantities in the described behaviour path of the simulation of the scenario 1 “Water abstraction affects physical factors and temperature sensitive fish”.

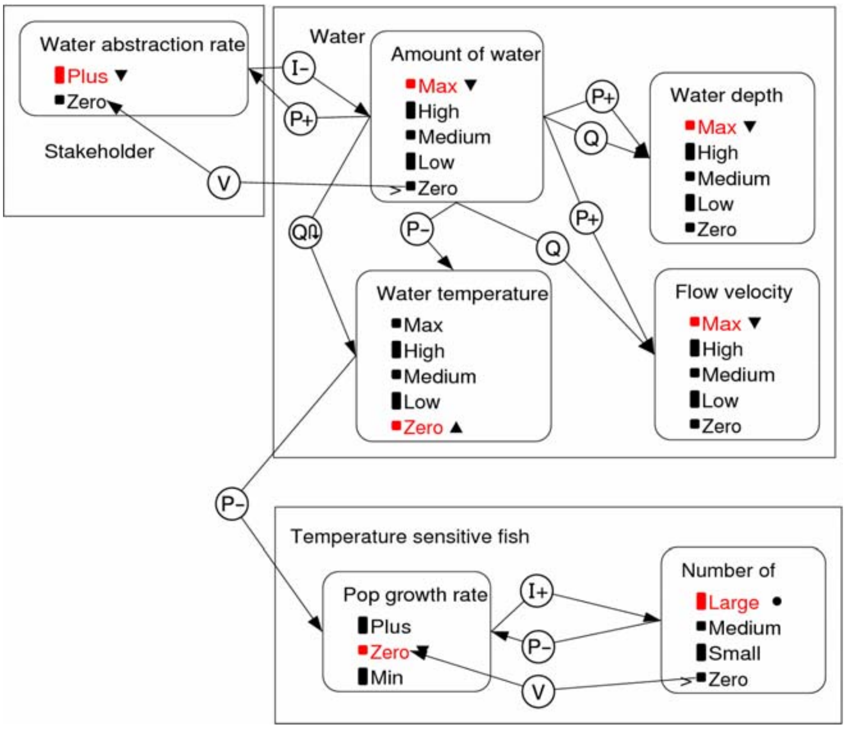


Figure 105: Detailed representation of the causal model in state 1of the scenario 1 "Water abstraction affects physical factors and temperature sensitive fish".

3.5.2 Scenario 2 "Water abstraction affects physical factors and flow velocity sensitive fish"

This scenario represents how temperature sensitive fish are affected by water abstraction and follows the same principles as scenario 1 (Fig. 106).

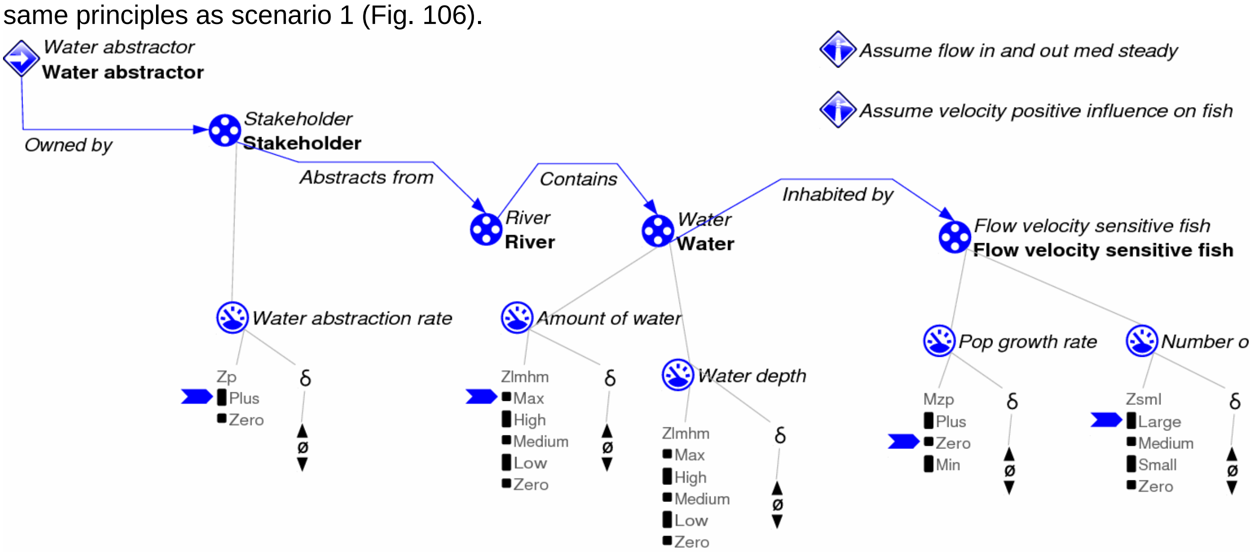


Figure 106: Scenario 2 "Water abstraction affects physical factors and flow velocity sensitive fish".

Table 17: Simulation summary of scenario 2 "Water abstraction affects physical factors and flow velocity sensitive fish".

Scenario name	"Water abstraction affects physical factors and flow velocity sensitive fish"
Full simulation	55 states
Initial states	[1]
End states	[20, 21, 22, 23, 26, 34, 35, 36, 37, 39, 40, 41, 42, 47, 48, 49, 50]
Relevant behaviour paths	[1, 2, 10, 25, 42]
Behaviour description	*Agent* abstracts water from *River*, physical factors (*Depth, Water temperature* and *Flow velocity*) are influenced and have an effect on fish. *Water depth* and *Flow velocity* are decreasing with decreasing *Amount of water* in the *River* and *Water temperature* is increasing; in this scenario negative consequences on the *Population growth rate* of fish sensitive to decreased flow velocities are modelled. All other quantities are similar to scenario 1.

3.5.3 Scenario 3"Water abstraction affects physical factors and all kinds of sensitive fish"

This scenario represents how temperature sensitive and flow velocity sensitive fish are affected by water abstraction and combines scenario 1and 2 (Fig. 110).

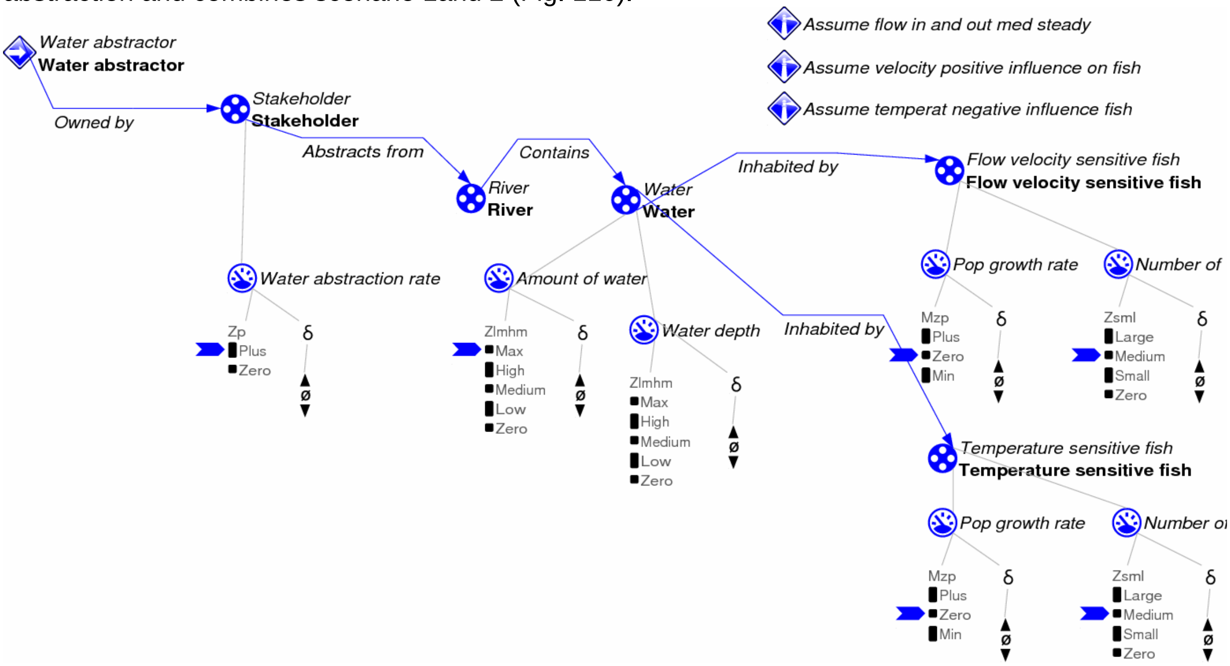


Figure 107: Scenario 2 "Water abstraction affects physical factors and all kinds of sensitive fish".

Table 18: Simulation summary "Water abstraction affects physical factors and all kinds of sensitive fish".

Scenario name	"Water abstraction affects physical factors and all kinds of sensitive fish"
Full simulation	68 states
Initial states	[1]
End states	[20, 21, 23, 24, 29, 30, 32, 33, 42, 43, 44, 46, 48, 52, 53, 55, 56, 61, 62, 64, 65]
Relevant behaviour paths	[1, 2, 6, 15, 50, 55] and [1, 2, 6, 15, 50, 56] and [1, 2, 6, 15, 50, 53] and [1, 2, 6, 15, 50, 52]
Behaviour description	This simulation shows the total picture presented first separated in scenario 1 and scenario 2: *Temperature sensitive fish* are decreasing with increasing *Water temperature* and *Flow velocity sensitive fish* are also decreasing with decreasing *Flow velocity*; all physical factors are dependent on a reduction of the *Amount of water* in the *River.*

3.5.4 Scenario 4 "Water abstracted and supplied for reservoir, physical factors and temperature sensitive fish affected"

This scenario introduces the idea of water abstraction and subsequent supply to a reservoir; the rest of the model follows the principles of scenarios 1-3; here the effect of a reduced amount of water on temperature sensitive fish species is modelled.

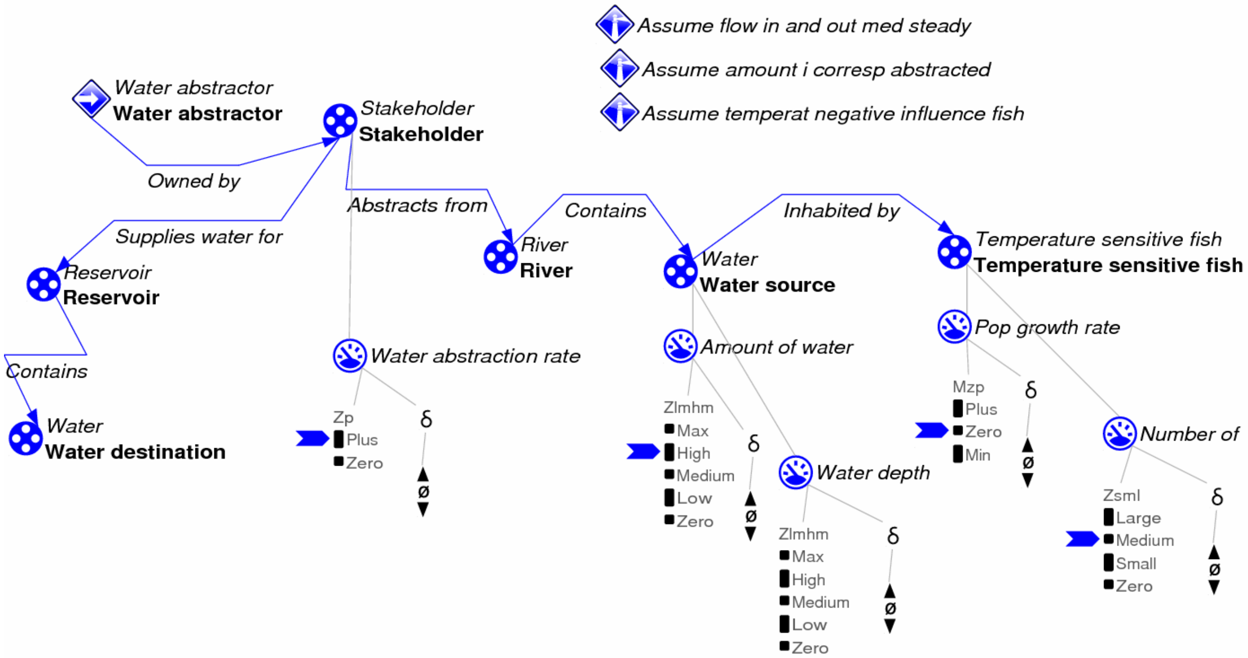


Figure 108: Scenario 4 "Water abstracted and supplied for reservoir, physical factors and temperature sensitive fish affected"

Table 19: Simulation summary of scenario 4"Water abstracted and supplied for reservoir, physical factors and temperature sensitive fish affected"

Scenario name	"Water abstracted and supplied for reservoir, physical factors and temperature sensitive fish affected"
Full simulation	24 states
Initial states	[1]
End states	[9, 10, 12, 13, 16, 19, 20, 22, 23]
Relevant behaviour paths	[1, 2, 4, 7, 18, 20] and [1, 2, 4, 7, 18, 21]
Behaviour description	The Amount of water in the river stays first at high for the first modelling steps, although the population growth rate of temperature sensitive fish goes to minus in the second modelling step; then the abiotic factors follow the decrease of the *Amount of water*. The most important difference to the scenarios 1-3 is the concept of a reservoir being filled by the abstracted water.

3.5.5 Scenario 5 "Water abstracted and supplied for reservoir, physical factors and flow velocity sensitive fish affected"

This scenario introduces the idea of water abstraction and subsequent supply to a reservoir; the rest of the model follows the principles of scenarios 1-3; here the effect of a reduced amount of water on flo velocity sensitive fish species is modelled.

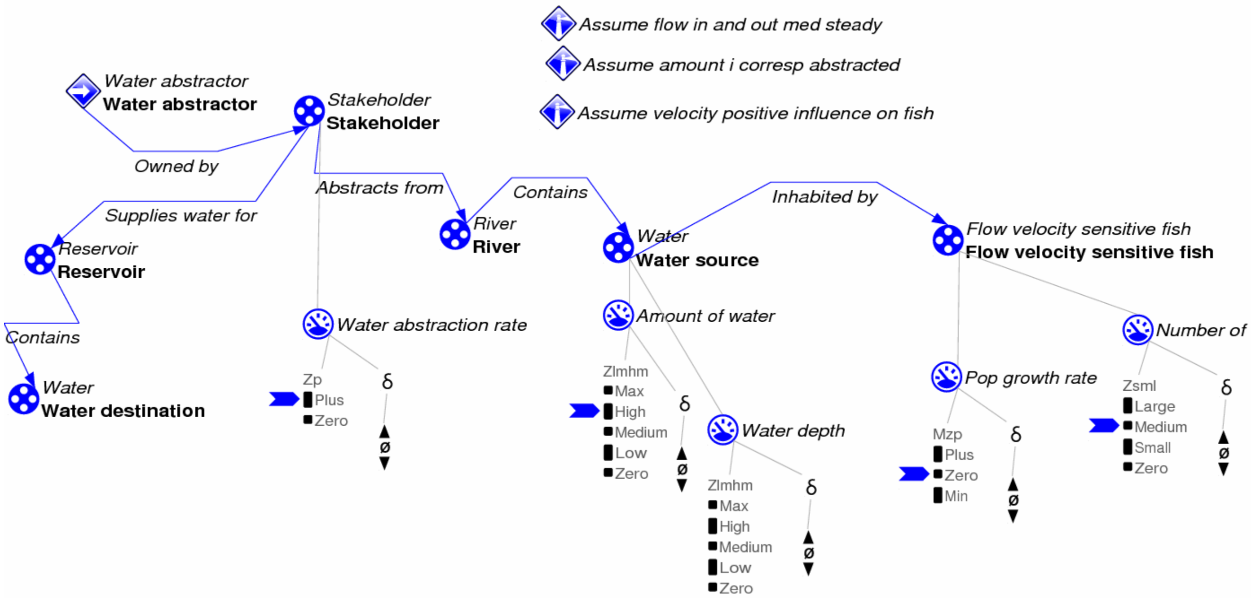


Figure 109: Scenario 5 "Water abstracted and supplied for reservoir, physical factors and flow velocity sensitive fish affected"

Table 20: Simulation summary of "Water abstracted and supplied for reservoir, physical factors and flow velocity sensitive fish affected"

Scenario name	"Water abstracted and supplied for reservoir, physical factors and flow velocity sensitive fish affected"
Full simulation	24 states
Initial states	[1]
End states	[9, 10, 12, 13, 16, 19, 20, 22, 23]
Relevant behaviour paths	[1, 2, 4, 7, 18, 20] and [1, 2, 4, 7, 18, 19]
Behaviour description	The Amount of water in the river stays first at high for the first modelling steps, although the population growth rate of flow velocity sensitive fish goes to minus in the second modelling step; then the abiotic factors follow the decrease of the *Amount of water*. The most important difference to the scenarios 1-3 is the concept of a reservoir being filled by the abstracted water.

3.5.6 Scenario 6 "Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected"

This scenario introduces the idea of water abstraction and subsequent supply to a reservoir; the rest of the model follows the principles of scenarios 1-3; here the effect of a reduced amount of water on both temperature sensitive fish species and flow velocity sensitive fish species is modelled.

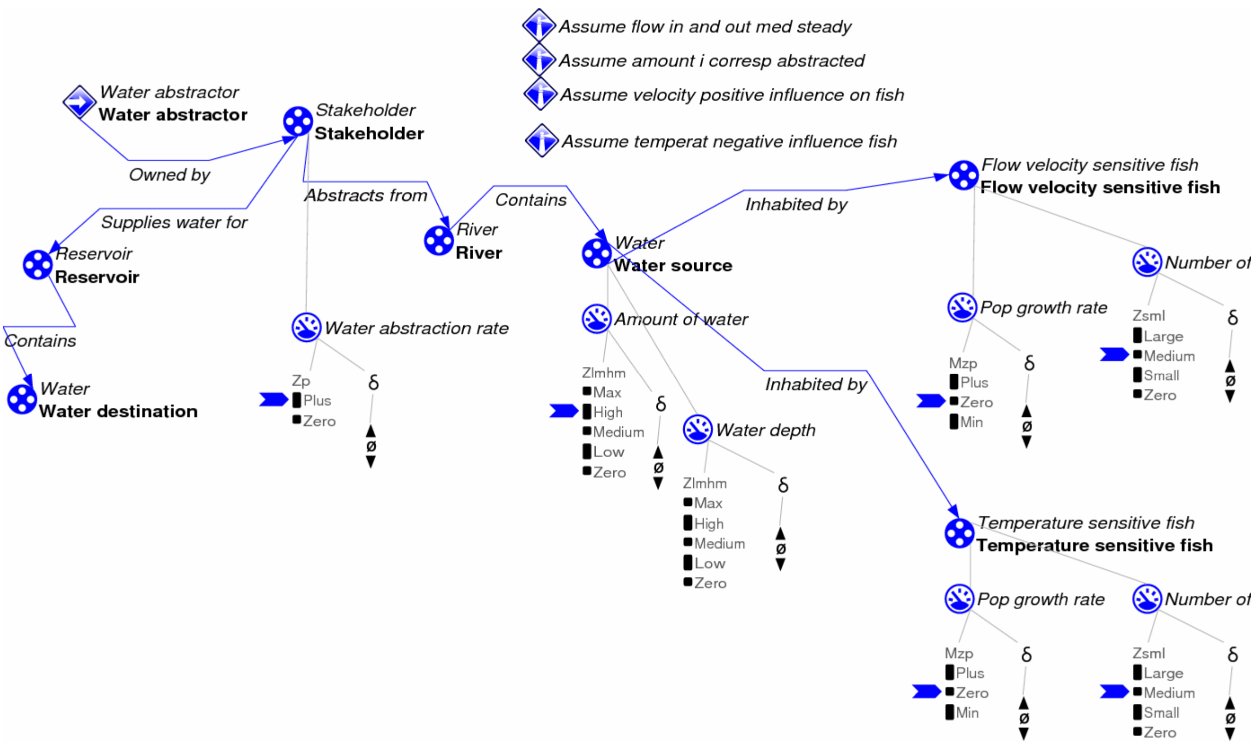


Figure 110: Scenario 6 "Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected".

Table 21: Simulation summary scenario 6 "Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected".

Scenario name	"Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected"
Full simulation	68 states
Initial states	[1]
End states	[20, 21, 23, 24, 29, 30, 32, 33, 42, 43, 44, 46, 48, 52, 53, 55, 56, 61, 62, 64, 65]
Relevant behaviour paths	[1, 2, 6, 15, 50, 56] and [1, 2, 6, 15, 50, 53] and [1, 2, 6, 15, 50, 55] and [1, 2, 6, 15, 50, 52]
Behaviour description	This simulation shows the total picture presented first separated in scenario 4 and scenario 5: *Temperature sensitive fish* are decreasing with increasing *Water temperature* and *Flow velocity sensitive fish* are also decreasing with decreasing flow velocity; all physical factors are dependent on a reduction of the *Amount of water* in the *River,* and the *Amount of abstracted water* goes to <Maximum> in the *Reservoir.*

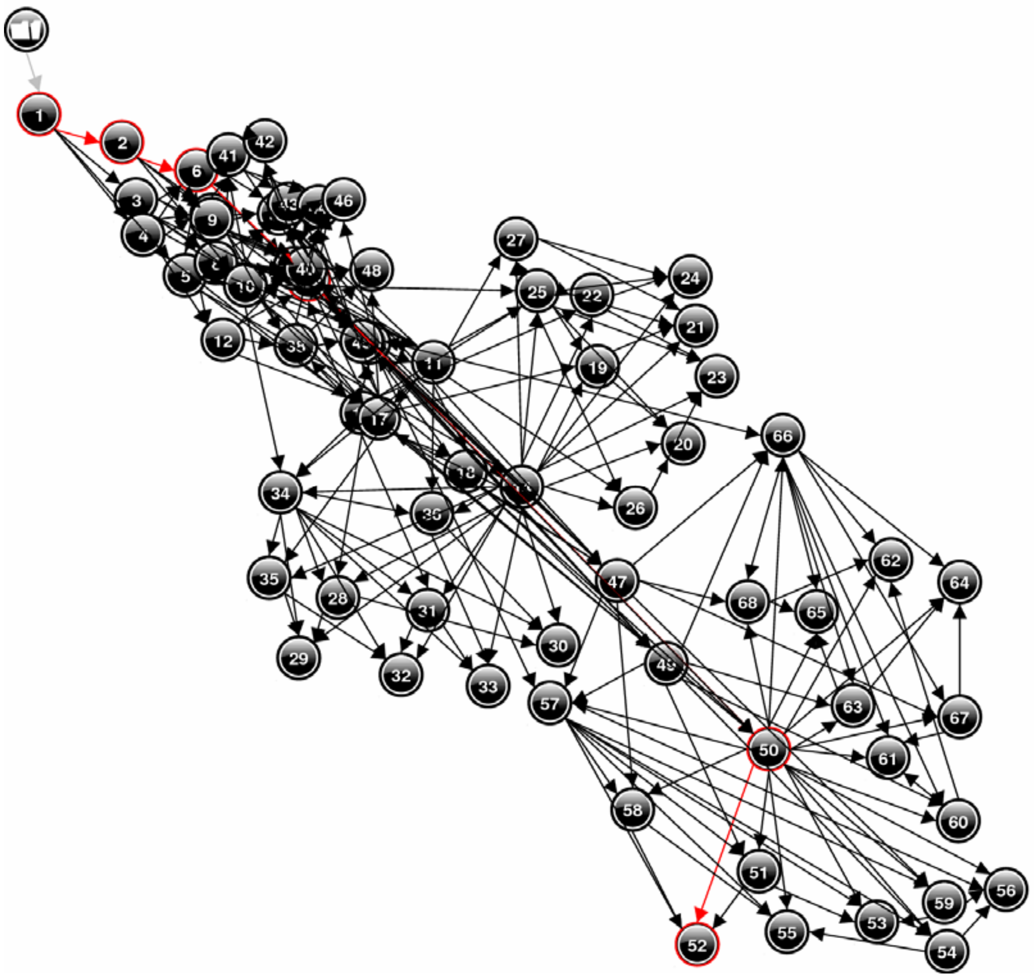


Figure 111: Behaviour graph obtained in a simulation of scenario 6 “Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected”.

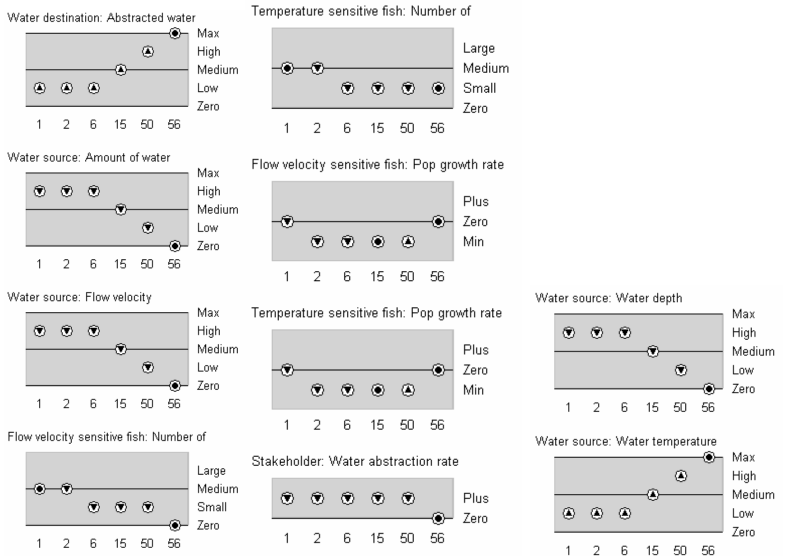


Figure 112: Value history diagrams of the quantities in the described behaviour path of the simulation of scenario 6 “Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected”.

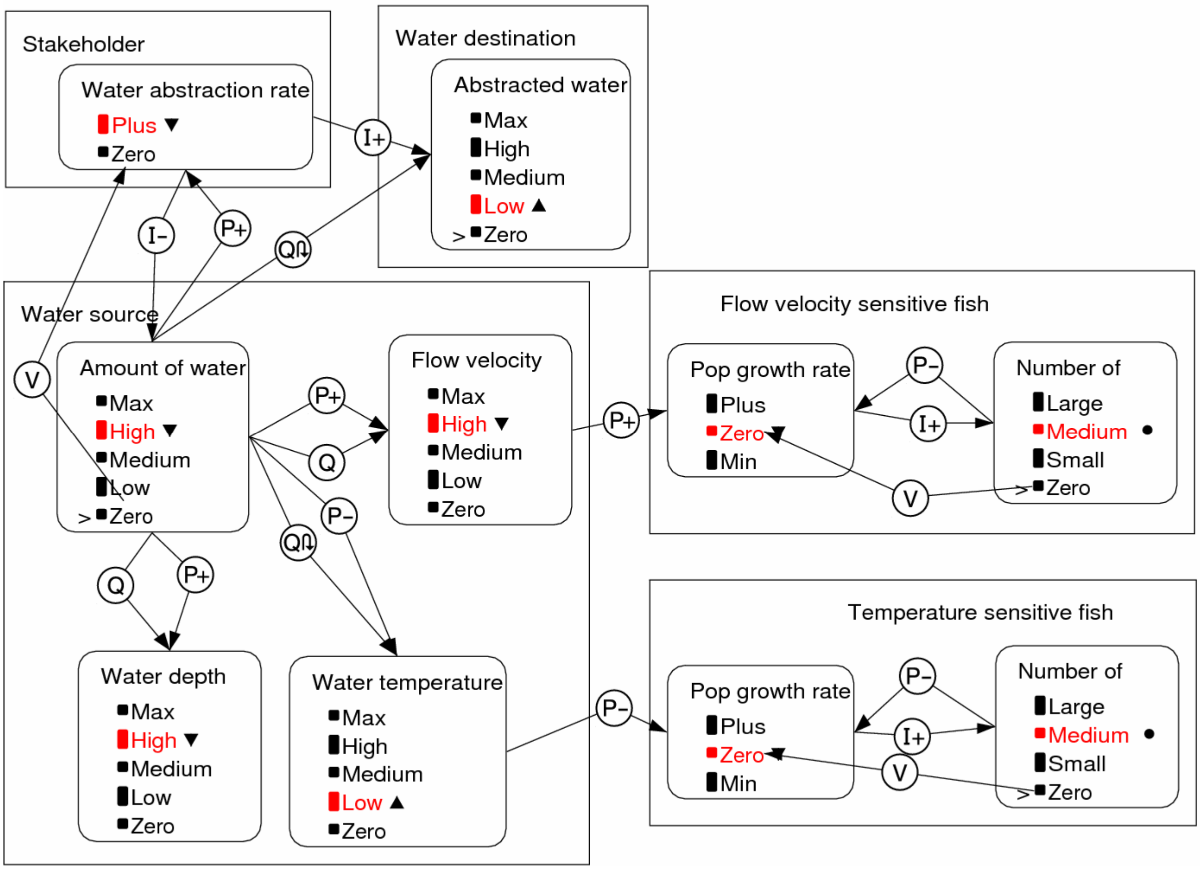


Figure 113: Detailed representation of the causal model in state 1 of the simulation of scenario 6"Water abstracted and supplied for reservoir, physical factors and all kinds of sensitive fish affected".

3.5.7 Scenario 7 "Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected"

This scenario introduces the idea of energy production related to *Stakeholder (Private owner) Profit* and *Satisfaction* (Fig. 126); no effects on physical factors and fish are modelled here.

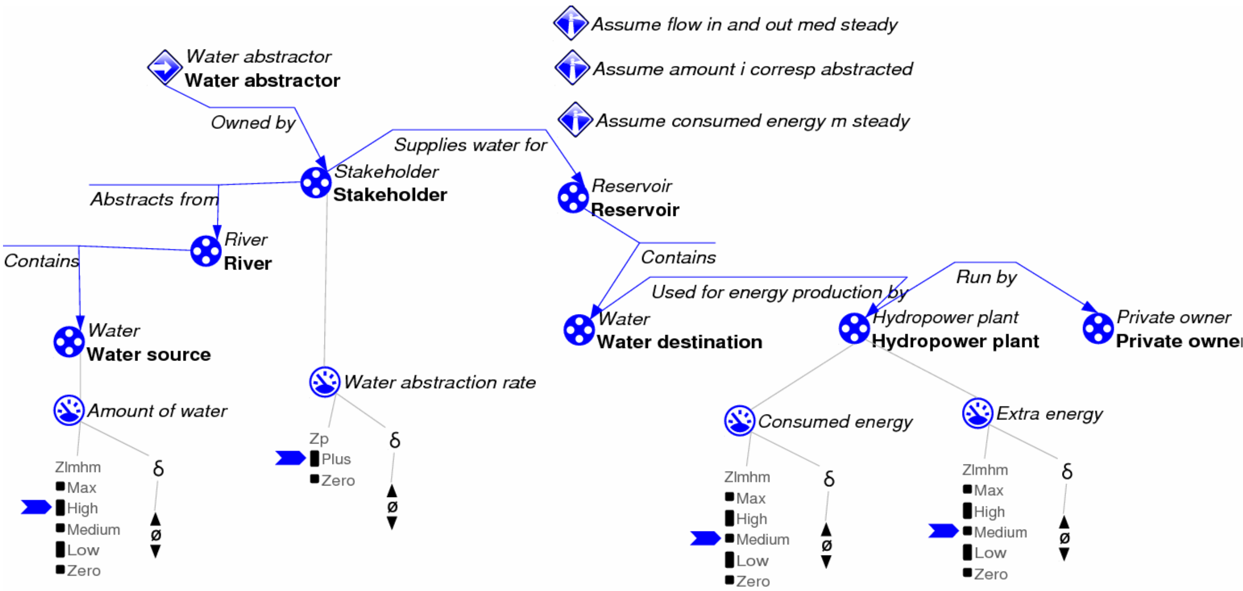


Figure 114: Scenario 7 "Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected".

Table 22: Simulation summary of scenario 7"Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected".

Scenario name	"Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected"
Full simulation	21 states
Initial states	[1]
End states	[3, 5, 6, 19, 20, 21]
Relevant behaviour paths	[1, 2, 7, 8, 12, 20]
Behaviour description	The *Amount of water* abstracted corresponds to the *Amount of water* supplied for the *Reservoir*, where it is used for *Energy production*; as the *Generated energy* increases, the relationship between *Produced* and *Consumed energy* becomes <Positive>, positively influencing *Profit* and *Stakeholder satisfaction*, which goes to <High> and do NOT reach its maximum. In this scenario no effects on physical factors or fish are modelled.

3.5.8 Scenario 8"Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected"

This scenario shows the most detailed picture of water abstraction and reservoir supply, change of physical factors in the river influencing sensitive fish species, energy production and profit related to stakeholder satisfaction (Fig. 134).

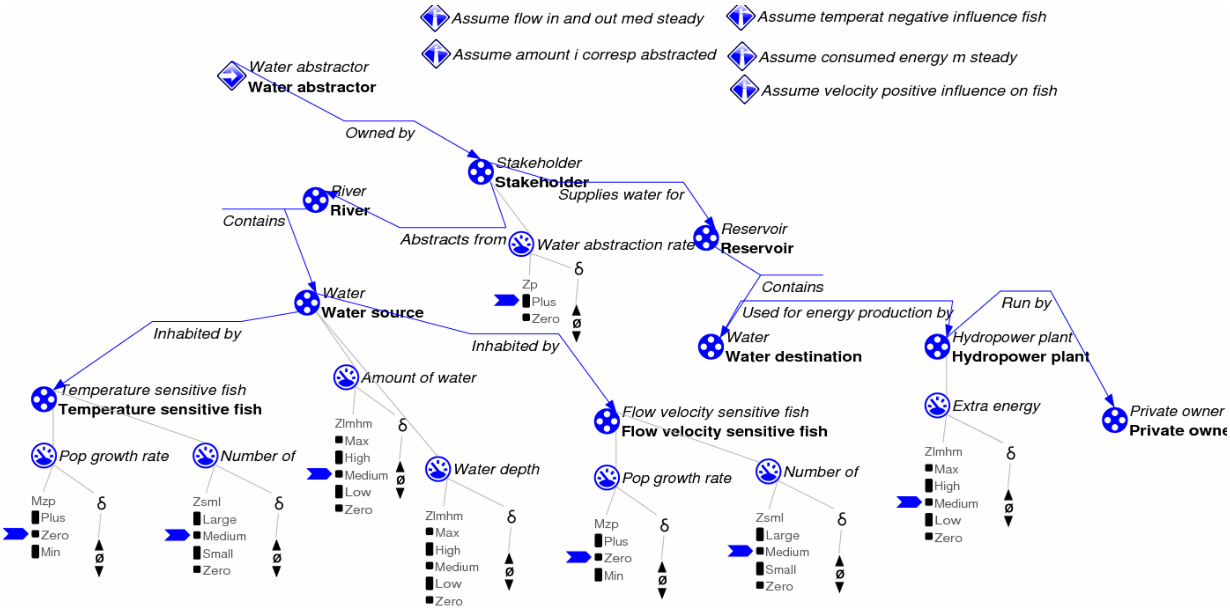


Figure 115: Scenario 8 "Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected".

Table 23: Simulation summary of scenario 8 "Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected".

Scenario name	"Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected"
Full simulation	54 states
Initial states	[1]
End states	[10, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 31, 34, 38, 39, 41, 42, 47, 48, 50, 51
Relevant behaviour paths	[1, 7, 24, 39] and [1, 7, 24, 48]
Behaviour description	Most initial values are set to <Medium> at the beginning of the scenario, and within the simulation the *Abstracted water* increases, the *Amount of water* (in the *River*) decreases with its related negative (*Depth* and *Flow velocity*) and positive (*Water temperature* effects) on fish; as the amount of supplied water (to the *Reservoir* for energy generation) increases, the amount of *Extra energy* also increases having a positive effect on *Profit* and *Stakeholder satisfaction*. As the *Amount of water* reaches <Zero> in the end only the behaviour graphs where the *Amount of fish* also reaches <Zero> are relevant. It makes no sense to have <Low> *Amount of fish* and <Zero> *Amount of water*. This simulation shows the full picture of model B, although we did not explicitly model the positive effect of water abstraction on indifferent species and species preferring/withstanding warmer water conditions.

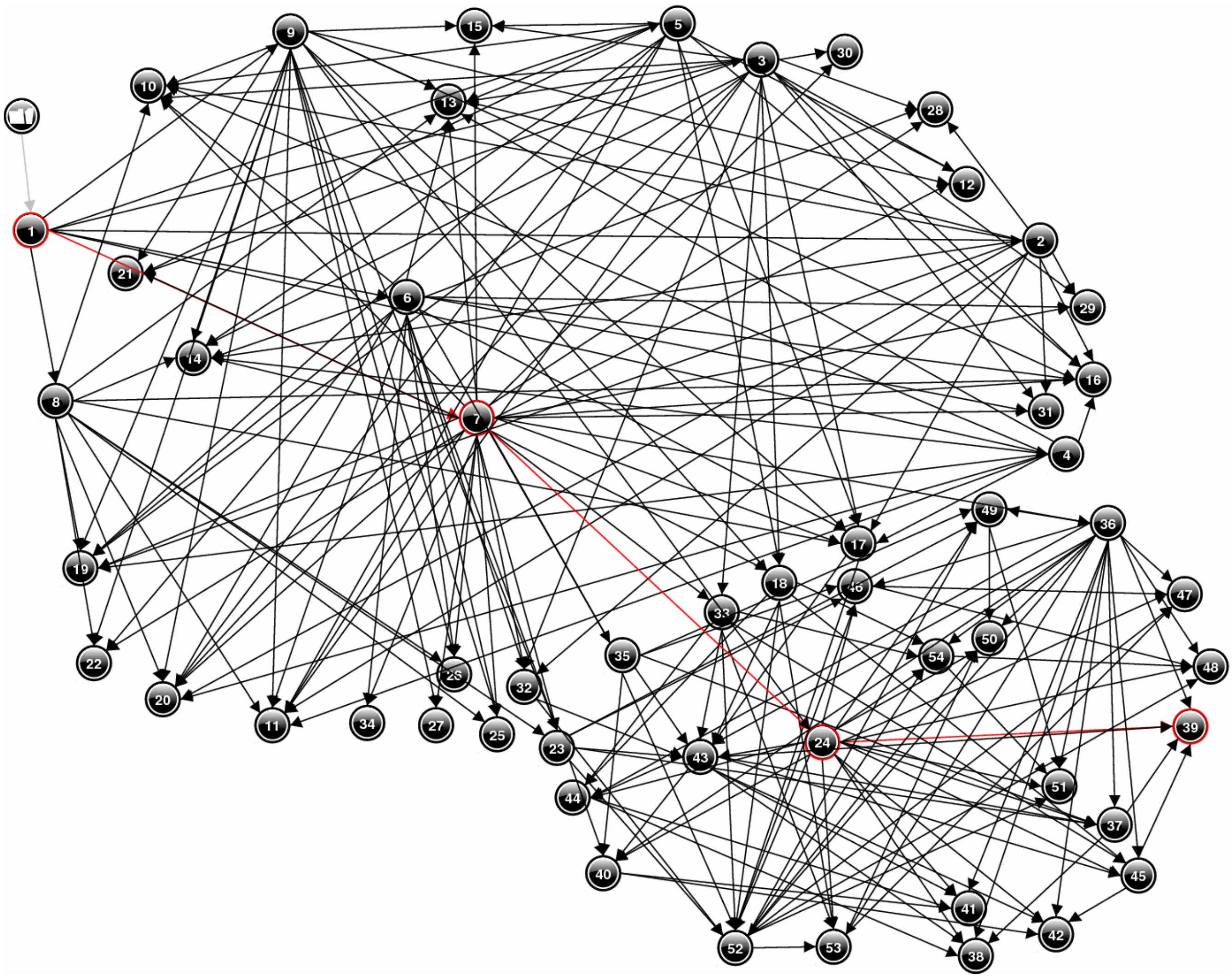


Figure 116: Behaviour graph obtained in a simulation of scenario 8 “Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected”.

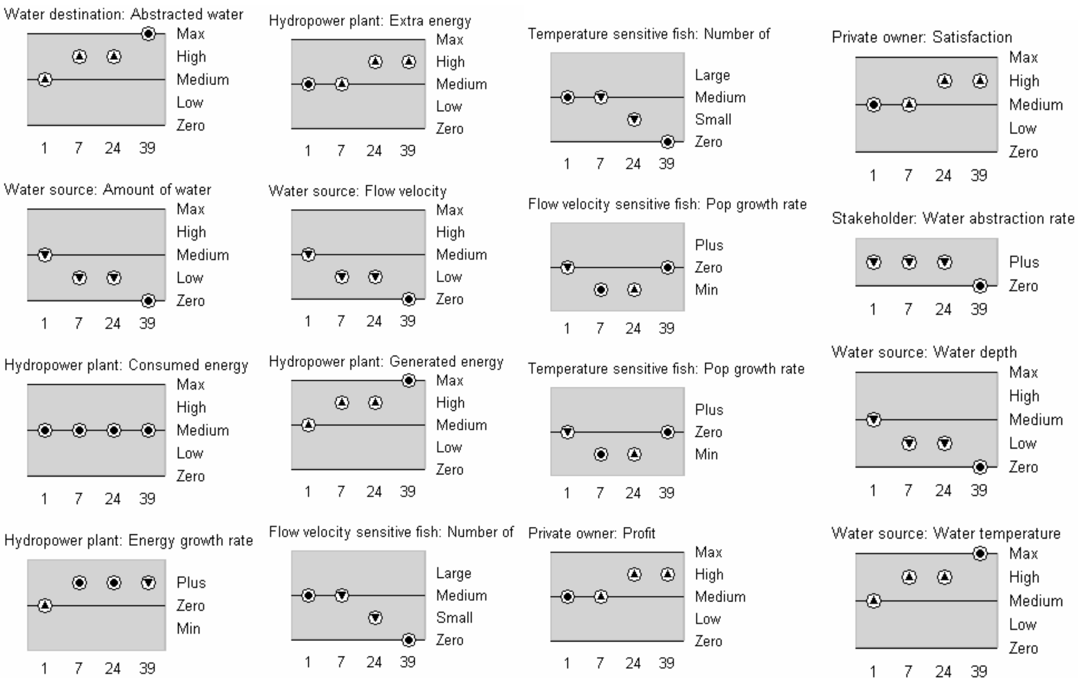


Figure 117: Value history diagrams of the quantities in the described behaviour path of the simulation of scenario 8 “Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected”.

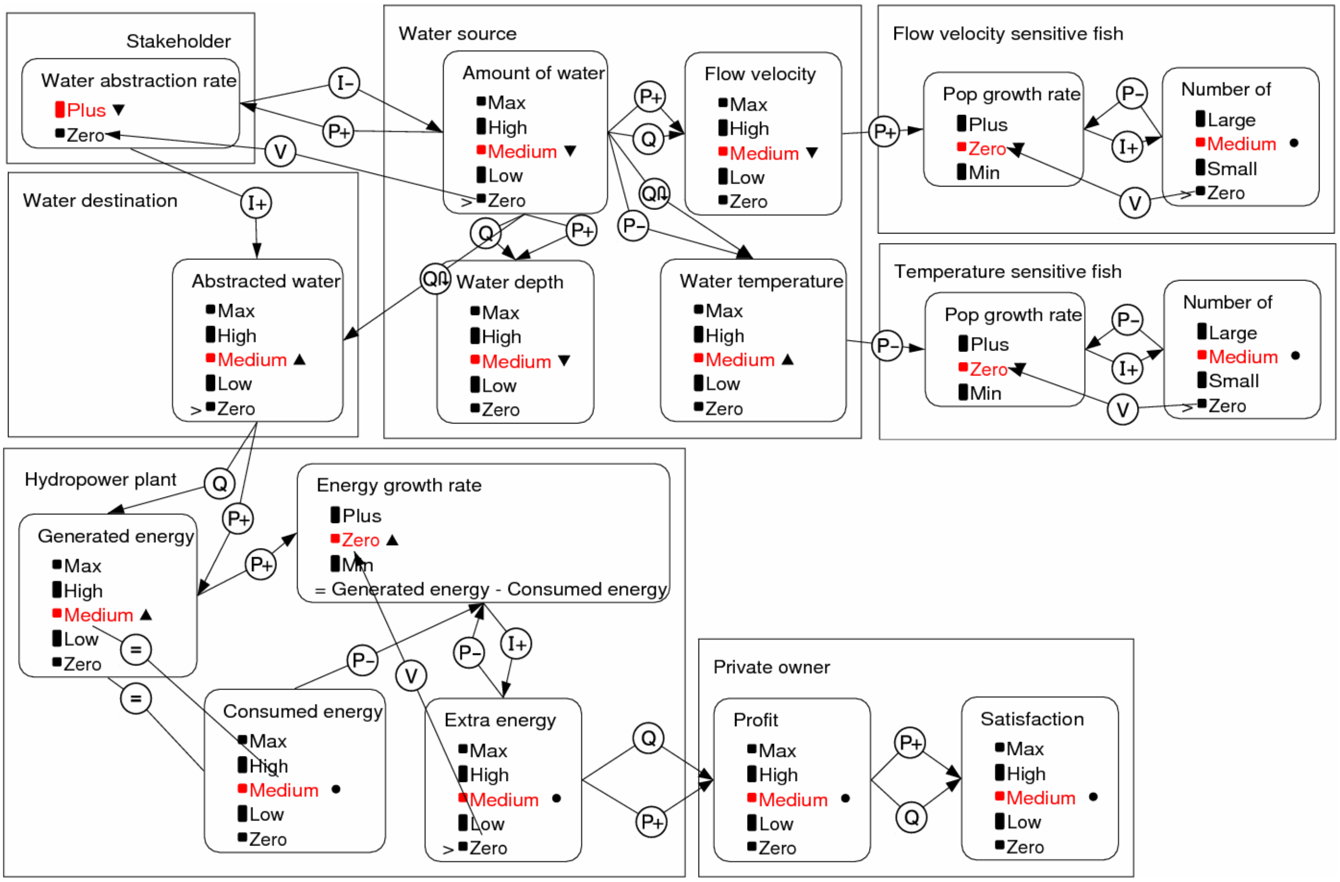


Figure 118: Detailed representation of the causal model in state 1 of the simulation of scenario 8 "Water abstracted and supplied for reservoir, profit and stakeholder satisfaction affected and all kinds of sensitive fish negatively affected".

4 Follow up

Although this is the final document of the River Kamp case study for the NaturNet-Redime project, there are many more features that can be explored based on the structure developed here. Especially a detailed implementation of a representation of the relationship between the described effects of water abstraction on temperature and flow velocity sensitive fish and the good ecological status required by Water framework directive could be very helpful learning material; this would require a more explicit representation of the parameters the WFD is asking for: biomass, age structure and species diversity.
Additionally a more detailed representation of a life cycle model, that is being developed the River Trent case study (Noble, 2006) and is available in future to be re-used, would help to link the different effects of a changed physical environment to the specific effects on a certain life stage more causally. Additionally it is an important task to explore in more detail the linkages of our models to the other models developed within the project (Cioaca et al., 2006; Noble, 2006; Salles & Rios Caldas, 2006; Uzunov et al., 2006).
There is also the problem that currently the water abstraction stretch of the river is treated as a "Container", with water temperature increase everywhere; a more natural representation would deal with the increase of water temperature related to the length of the water abstraction stretch.
At least, a more detailed representation of the influence of different abstraction modes of power plants on the natural water flow regime (especially the effect of turbine uptake capacity on the amount of water that is left in the river during increased discharges) would help to better capture a more natural representation of the effects of water abstraction on morphology (maintenance flows of habitats) and fish.

5 Conclusions

River catchments are complex systems. With our 2-model approach we tried to capture basic principles of human activities in a river catchment, related to management, ecological integrity and human well being. Model B, the water abstraction model is linked to model A which is a more or less management based model, via a specific stakeholder group, the private owner of a hydropower plant with strong private interests. The presented models and model fragments represents a comprehensive pool of learning material to be used to teach people about management of river catchments and impacts caused by water

abstraction on fish. The starting point of the sustainability processes in the river Kamp valley were catastrophic events that caused a high magnitude of catastrophic effects; this situation caused fear in the local population, which increased the pressure on politicians to become active. The target was the development of development plans for a sustainable future within the Kamp valley. We did our best, to capture exactly this situation taking the catastrophic event as a starting point, describing the basic circumstances under which the development of high quality sustainability plans is possible and linking important influences like private interests and resistance against measures to the actions that are implemented at the end of such a process.
The water abstraction model represents a powerful representation of the different modes of water abstraction active in the Kamp valley: abstraction and direct use and abstraction, storage in a reservoir with subsequent use. The chosen representation allows for a detailed exploration of the different effects of both modes on fish and also allows for a representation of positive and negative effects of fish – depending on the viewpoint chosen: modelling the decrease of sensitive species or modelling the increase of indifferent species under the same situation. Both situations are currently used to measure human pressures via fish indices (Pont et al., 2006). Focusing on management issues on a catchment level and relating human pressures and impacts to sensitive fish species, as required to the EU-Water Framework Directive, our model can be seen as an important contribution to the current EU policy on water related issues across Europe.
Concluding, we believe that the River Kamp model will meet the objectives defined in the beginning of the modelling effort: (1) to improve understanding of catchment based management activities and (2) to increase understanding of the effects of water abstraction on fish. The models represent a powerful tool to introduce the basic principles of the described topics to students and other stakeholders, like politicians and decision makers. They will help to support stakeholders in learning and becoming active on issues related to the sustainable development of riverine landscapes, and represents a well developed starting point for more detailed representation of sustainable development processes related to river catchments.

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