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CONSISTENT CONTEXT SCENARIOS: A NEW APPROACH TO 'STORY AND SIMULATION'

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Summary

This paper focuses on 'Story and Simulation' (SAS), an approach combining quantitative and qualitative scenario methods to explore environmental futures. The basic idea of SAS is to explore futures of coupled human-natural systems via numerical simulation models that are combined with qualitative storylines. This approach has important strengths compared with 'quantitative modeling only' approaches. For instance, SAS allows doing justice to the uncertainty and the (in part) qualitative character of future social, political and technological developments. Scenarios of global change resulting from SAS processes have been used for scientific purposes and have become relevant for informing and structuring public and political debates. At the same time, these scenarios have been criticized in terms of usefulness and credibility. SAS is challenged by its methodological imbalance as it combines formal and systematic modeling with creative-narrative scenario techniques. Furthermore, its promise that the mathematical models check the internal consistency of the storylines might be difficult to hold in practice. Therefore, a new approach is discussed: I propose to test the combination of the cross-impact balance analysis (CIB) with simulation models. CIB is a qualitative but systematic form of systems analysis, using a balance algorithm to generate consistent scenarios. The guiding question is how CIB could be used within a new approach to SAS and what potential benefits and limits one can expect from CIBAS (i.e. 'CIB And Simulation').

This work is mainly based on literature review. SAS is described and discussed with regard to its strengths and weaknesses. Building on literature review on CIB and on conceptual ideas on 'CIBAS', expectations on potential and limits of its application are formulated.

This work suggests that SAS can – at least in part – be improved, e.g., by combining the cross-impact balance analysis with simulation models. Generally, within CIBAS the 'intuitive logics' approach of SAS could be complemented or replaced by the systematic CIB. CIBAS could be designed, e.g., in form of 'consistent context scenarios', with CIB scenarios providing numerical models with consistent, qualitative context scenarios that can be quantified and used as input parameter for simulation runs. I expect CIBAS a) to balance the methodological imbalance of SAS by its systematic and transparent approach; b) to support the reproducibility of the scenario *process* (not the result) by explicitly documenting underlying mental models, especially on interrelations; c) to assure the internal consistency of the qualitative scenarios. Still, in practice, CIBAS is expected to be ridden with many of the same prerequisites as the ideal type SAS: Furthermore, CIBAS might tend to overemphasize causal relationships. Overall, the expected benefits suggest that the approach could enhance the usefulness and credibility of SAS for internal as well as for external users.

1 Introduction

1.1 Approaching futures of coupled human-environmental systems

The analysis of (possible) futures of coupled human-environmental systems is faced with major challenges. The future of social, economic, political and technological developments often is not predictable but uncertain, and “the same uncertainties that complicate projecting socio-economic trends also hamper our ability to foresee environmental futures“ (EEA 2007: 38). Furthermore, future social developments interact with each other and with natural systems; interactions within social systems and between society and environment are complex. These complex influence networks cannot always be described comprehensively and appropriately in quantitative ways but additional qualitative information often reveals necessary. Overall, to explore futures of coupled human-environmental systems, interdisciplinary cooperation is required to obtain relevant systems knowledge.

Classically, scenarios of environmental futures have been based on modelling and simulation, whereas in other forward looking fields (e.g. in business contexts) rather qualitative approaches have prevailed. But the field of environmental change research has opened up to policy advice on one hand and to disciplines as e.g. economics and cultural studies on the other hand and many forms of methodological integration have been developed as Integrated Assessment Modelling (IAM), e.g. In the last decade, the field has designed a specific approach to develop environmental scenarios, namely via a combination of ‘quantitative’, i.e. numerical mathematical models (of environmental systems) with so called storylines, that contain ‘qualitative’, i.e. verbal i.e. linguistic information on possible futures (e.g. socio-economic futures). This methodological combination has been labelled “Story And Simulation (SAS)” (Alcamo 2001, 2008).

Scenarios resulting from SAS processes have become relevant for structuring public and political debates, as for instance the emission scenarios published by the IPCC (2000) used in the Third and Fourth Assessment Report (2001 and 2007). But at the same time, these scenario *processes* and their *products* (Hulme/Dessai 2008) have been criticized and questioned in terms of transparency, usefulness (e.g. Parson 2008, Schweizer 2010), scientific credibility (e.g. Hulme/Dessai 2008, O’Neill et al. 2008) and effectiveness (e.g. Girod et al. 2009). There is an ongoing discussion, how to generate scenarios of global change that are useful and credible for different types of users (e.g. Parson 2008), as “producer-users” (internal users) and potential “recipient-users” (external users) (Pulver/VanDeveer 2009).

1.2 Focus of this paper

The first aim of this paper is to reflect SAS as a method that combines qualitative and quantitative scenario approaches to explore environmental futures. The second aim is to propose a methodological variant, using a systematic but still qualitative scenario technique instead of storylines, namely the cross-impact balance analysis (CIB) (Weimer-Jehle 2006) and to combine it with numerical simulation models. I ask how CIB could be used within a new approach to SAS and what potential benefits and limits one can expect from CIBAS (i.e. ‘CIB And Simulation’). This work is mainly based on literature review and completed by several expert interviews. SAS is described and discussed with regard to its strengths and weaknesses (chapter 2). Based on a review of literature on CIB and on some general conceptual ideas on CIBAS, expectations on potential and limits of its application are formulated (chapter 3).

2 'Story And Simulation' – strengths and weaknesses

2.1 'Story And Simulation' (SAS)

The basic idea of SAS is to explore futures of coupled human-natural systems by combining numerical simulation models with qualitative storylines (or 'narratives'). Under the label of SAS, the approach has been promoted by Alcamo (e.g. 2001, 2008), methodological reflections on 'hybrid scenarios' also have been formulated by Kemp-Benedict (2004) and Winterscheid (2007).

There are two assumptions underlying the SAS approach. The first assumption is that the combination of so called 'qualitative' with so called 'quantitative' scenario approaches could benefit from the advantages of both (Alcamo 2008: 124; Kemp-Benedict 2004:1; Winterscheid 2007: 54). A summary of the respective advantages of both types of scenario approaches as seen by Alcamo is given in table 1. Both types of scenario approaches operate with a sort of "system model" (Walker et al. 2003: 7). The combination of ‚hard' (i.e. numerical) and ‚soft' (i.e. verbal, conceptual) system models is assumed to allow for a more appropriate representation of complexity and uncertainty and thus for a deeper and more comprehensive understanding of the system under study.

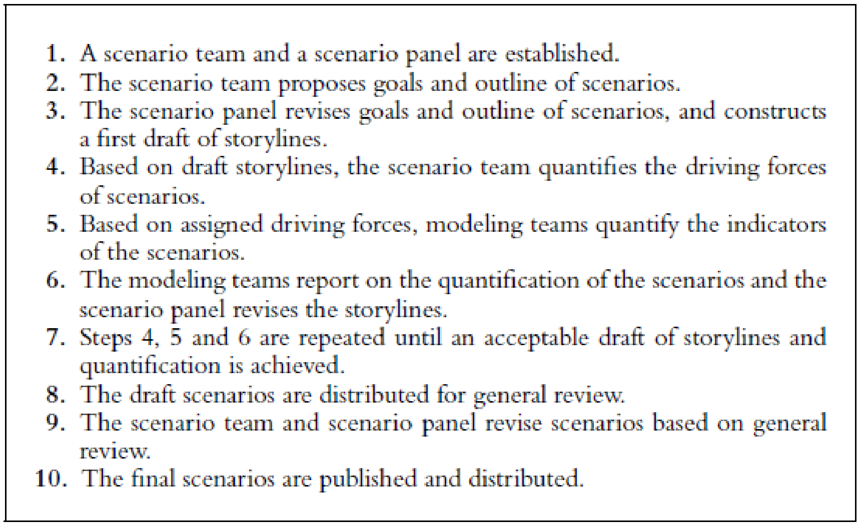
table 1: Advantages of qualitative vs. quantitative scenario approaches (based on Alcamo 2008: 124 ff.)

qualitative scenario approaches ideal type: storyline or narrative text	**quantitative scenario approaches** ideal type: based on computer models
Represent heterogeneous perspectives of diverse stakeholders and experts More interesting and comprehensive than „dry tables of numbers or confusing graphs" Useful to collect experts' and policy makers' views on future social developments and their environmental implications Support to consider the 'bigger picture', also with regards to long time horizons and great geographical scales Useful to communicate issues and to raise awareness Useful to develop strategies	Provide numerical information and satisfy demand for quantitative scenarios from environmental science and policy Assumptions are – at least in principle and for experts – transparent (equations, inputs, etc. documented) Based on published models (quality control via peer-review) Useful to explore, what assumptions have what environmental effect Useful for policy test and policy advise

The second assumption underlying SAS is that 'hard' system models *always* interact with 'soft' system models (cf. e.g. Winterscheid 2008: 37). This means, every formalized, numerical model is based on assumptions and on mental models that are perhaps partly implicit, but that should be made explicit in form of conceptual models to allow for critique and falsification.

Alcamo (2008: 137 et sqq.) describes the ideal type SAS approach as a process in ten steps (cf. figure 1). On the methodological level, the process is based on a common definition of the scenario aim and scope (step 1 and 2). Then, a first version (draft) of qualitative storylines is generated defining central themes and the time frame (step 3). The assumptions on driving forces underlying the storylines are quantified. These quantifications can rely on multiple sources as reference studies, own analysis of time series, model runs or expert guesses (step 4). The quantified assumptions serve as input parameter for model runs to calculate indicators (i.e. output parameter of the models) (step 5).

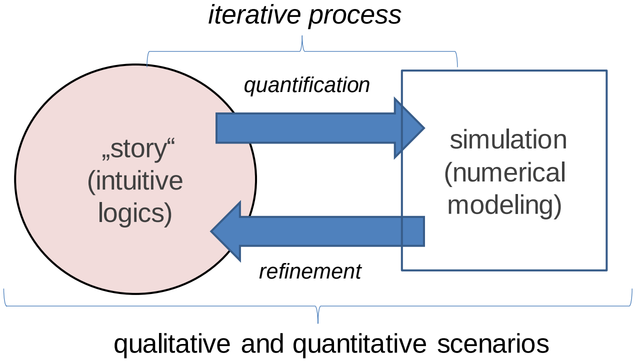
figure 1: SAS process (ideal type) (figure by Alcamo 2008: 138)



1. A scenario team and a scenario panel are established.
2. The scenario team proposes goals and outline of scenarios.
3. The scenario panel revises goals and outline of scenarios, and constructs a first draft of storylines.
4. Based on draft storylines, the scenario team quantifies the driving forces of scenarios.
5. Based on assigned driving forces, modeling teams quantify the indicators of the scenarios.
6. The modeling teams report on the quantification of the scenarios and the scenario panel revises the storylines.
7. Steps 4, 5 and 6 are repeated until an acceptable draft of storylines and quantification is achieved.
8. The draft scenarios are distributed for general review.
9. The scenario team and scenario panel revise scenarios based on general review.
10. The final scenarios are published and distributed.

Based on the model results, the storylines are refined, i.e. they are compared with the models and enriched with quantitative model results. Then a second version is drafted (step 6). Steps 4 to 6 are iterated (2-3 times) until complete and sound qualitative *and* quantitative scenarios are established (step 7). The scenarios are broadly distributed for multiple feedbacks and reviews (step 8), storylines and model runs are revised (step 9) and the final scenarios published and disseminated (step 10).

figure 2: Summary of ideal type SAS, own representation based on Alcamo 2008



On the 'social' level, Alcamo (2008: 137) proposes to compose a *scenario team,* i.e. a small core group responsible for the coordination between the *scenario panel* on the one hand, i.e. a bigger group responsible for the qualitative storylines that can include additional stakeholders and experts, and the *modeling team* on the other hand responsible for the quantification of the assumptions and the modeling. Alcamo stresses that in the scenario team, experts are required who know what quantifications are necessary and what quantifications are possible. It is mainly in step 8, when the scenarios are distributed for general review, that *decision makers* are explicitly mentioned as participants of the process.

In fact, the ideal type SAS as described above is a (generalized) conceptual proposition based on different methodological designs realized beforehand. Examples of empirical prototype projects in which forms of SAS have been applied are the Millennium Ecosystem Assessment (MA) (Carpenter et al. 2005), the IPCC emission scenarios (IPCC 2000), the Global Environmental Outlook with the GEO-4 scenarios (UNEP 2007, Rothmans/Agard/Alcamo 2007) and the 'World Water Visions' (Gallopin/Rijsberman 2000) (for a comprehensive overview cf. also Henrichs et al. 2009, Rothmans 2008).

These projects all reveal individual methodological designs that deviate from the ideal type SAS described above. The label 'SAS' thus covers a variety of approaches combining numerical models with qualitative storylines. These variants can be distinguished at least with regard to position and timely succession of both components (iterative, parallel or consecutive), role in and 'dominance' of the process (models dominate, storylines dominate or equal weight of the two), degree and structure of overlap of the scopes of the two components as well as structure and degree of their integration.

The qualitative scenario techniques used in these exercises belong to the group of "holistic" (Tietje/Scholz 2002) or "creative-narrative" (Kosow/Gaßner 2008) scenario techniques and can be identified as forms of the "intuitive logics" (IL) approach (cf. Schweizer 2010: 7 ff.) – even if they are rarely labeled as such. IL has been developed since 1970 (Wack 1985) and has its origins in business contexts. Its central feature is to work with those experts, who know best about the issue under study (Wilson 1998). The scenario writing approach makes use of all sorts of available knowledge, including intuitive knowledge. Often, driving forces are identified and discussed with regard to their degree of uncertainty and their importance. The 'scenario logics' are then build around the main uncertainties. Sometimes, two (independent) main uncertainties are considered, their two extreme developments defined and combined to span a matrix of four different worlds (cf. e.g. Henrichs et al. 2009). The qualitative scenarios then are developed in form of narrative texts with "compelling storylines" (Morrison/Wilson 1997)" and "highly descriptive titles" (ibid.). Mostly, the scenarios do not only consist in pictures of the futures (states) but are "sequential" (Schweizer 2010), i.e. unfold sequences of events and developments leading to these pictures of the future.

2.2 Strengths and weaknesses

SAS approaches have important strengths in developing scenarios of coupled human-environmental systems. This holds true especially when compared with 'modeling only' approaches as classical forms of systems analysis or integrated modeling, where system models represent environmental systems and are driven by external societal factors or where multiple environmental models are linked with economic models representing the social sphere. In both cases, future system developments are simulated via model runs based on sets of external drivers producing change in the system.

The first strength of SAS consists in representing the uncertainty of future social developments by using the scenario concept in its primary sense: Possible future developments of the system under study are not driven by isolated external parameter, but are contextualized by plausible, coherent and alternative pictures of futures. System change is not driven by single predictions or projections (and varied via sensitivity analysis), but by meaningful bundles of future developments of the system and its context. Considering the fact that predictive model results strongly depend on their assumptions on uncertain external drivers; an appropriate representation of these drivers and of their uncertainty can enhance the quality of the model results in a significant way.

A second strength is that SAS approaches allow to open future spaces not only in quantitative ways by using (model based) trend projections of available indicators, but that in addition, they are able to process qualitative information. Especially when mid and long term futures are concerned, qualitative descriptions often are more appropriate. SAS furthermore allows to combine qualitative with quantitative knowledge and thus to integrate both in a field normally dominated by quantitative approaches.

The third strength of SAS is its ability to include a) different types of knowledge; b) heterogeneous participants, e.g. experts from different disciplines and also – at least in principle – non-scientific stakeholders as, e.g., decision makers.

Overall, SAS has been developed as an answer to the limited capacity of 'modeling-only' approaches a) to cope with the uncertain and qualitative character of social dimensions of environmental change and b) to make useful and credible scenarios for different user groups (Alcamo 2008: 141).

Despite these benefits, there are also important weaknesses. First, SAS is characterized by a methodological imbalance between its formal and systematic component (i.e. modeling and simulation) and its creative and intuitive component (i.e. the storylines). The perceived scientific credibility of combined results is hampered by one component perceived as creative and intransparent and one component perceived as scientific – an assessment that might not do justice to either, as both, qualitative and quantitative scenarios include subjective and creative elements as well as sound facts. SAS seems to be a pragmatic methodological choice responding to multiple and perhaps in part conflicting requirements. But its IL approach to qualitative scenarios might not provide an optimal solution for including qualitatively oriented research into exercises with exploratory and scientific goals.

Weakness number two is the question of reproducibility of the storylines (cf. also Alcamo 2008). Storylines are based on multiple, complex and differentiated assumptions and mental models of coupled human-environmental systems and "even though they may be based on a more sophisticated concept of an environmental system than portrayed by any mathematical model" (Alcamo 2008: 142 et seq.), the assumptions are not transparent and not explicitly documented, and, in consequence, the storylines are difficult or impossible to reproduce. Alcamo proposes as a possible solution to use visualizing techniques as causal loop diagrams or cognitive maps that depict system elements and, most important, the relations between these elements. The challenge of such visualizations then is that they easily become very complex, when picturing all interrelations. Therefore, research on new approaches is needed (cf. Alcamo 2008: 143).

Third, a central idea of SAS is that the mathematic modeling allows checking the internal consistency of the storylines (cf. e.g. Alcamo/Van Vuuren/Ringler 2005: 148, Alcamo 2001: 28, 2008: 137, Kemp-Benedict 2004: 3, Greeuw et al. 2000: 91, Gallopin/Rijsberman 2000: 5). Different levels of internal consistency can be distinguished. SAS might not be equally strong in assuring internal consistency on these different levels.

On a first level, the consistency between the storylines and "current knowledge" (Alcamo/VanVuuren/Ringler 2005: 148) is at stake. The quantification of drivers described qualitatively in the storylines indeed forces to be precise and to refine definitions and descriptions used, furthermore it allows checking whether there are indicators and data available to triangulate assumptions expressed qualitatively by the storylines and finally, a numerical model is able to calculate indicators which in the storylines are expressed by qualitative descriptions or estimations only. But the absence of data or projections does not prove per se that qualitatively expressed assumptions are wrong; and the notion of 'current knowledge' should not be limited to quantitative knowledge only.

On a second level, the consistency between storylines and model(s) is at stake. The translation of driving forces of the qualitative scenarios into sets of input parameters for the model(s), can, if well done, assure a sort of congruence between the qualitatively formulated assumptions of the storylines on future developments on the one hand and the quantitatively expressed assumptions on driving forces of the models on the other hand. But therefore, a full *iterative* SAS process is imperative. In contrast, to achieve full consistency between storylines as a whole and a model as a whole, very demanding procedures of reciprocal structural adaptation would be necessary, going far beyond what is understood by SAS by now.

On a third level, 'internal consistency' refers to the fact that the storylines in themselves 'make sense', i.e. that the assumptions on the future developments of different drivers and factors of storyline *or* of one set of model input parameters are in themselves logical and non-contradictory. There are hints that this has not always been achieved in SAS scenarios: Schweizer (2010) points out that some of the storylines of the SRES scenarios (IPCC 2000) might contain contradictory elements because of ignored interdependencies between different future developments.

The fourth weakness is that in practice, the combination of narratives with simulation models is ridden with prerequisites. This point is also stressed by Alcamo (2008: 141 ff.), who points out that suitable models are needed that are compatible with qualitative storylines and that personal familiar with the respective models is required. I would like to add openness for non-classical modeling approaches, scenario-expertise, mutual understanding and respect as further necessary conditions. Another important aspect is the transformation of verbal into numerical statements and vice versa, „this conversion from the qualitative knowledge in the storylines to numerical model input is one of the weakest links in the SAS procedure" (Alcamo 2008: 139). Classically, this conversion is done via expert assessments, that are often neither transparent nor reproducible but follow 'rules of thumb' (cf. also Henrichs et al. 2009, Winterscheid 2007), Alcamo (2008) proposes a formalized solution based on Fuzzy Set Theory, recently, another formalized suggestion was made by Kemp-Benedict (2010) using Bayes' rule. These formalized solutions only partly cover the lack of transparency of the more subjective approaches, because they require additional assumption and tend to mask subjective assessments via numerical expressions. Overall, transformation rarely allows a perfect fit between the driving forces described by the storylines and those needed as input parameters by the models.

In sum, the SAS approach can be understood as a general methodological framework to combine numerical models and qualitative scenario techniques to develop scenarios of global change that has been flexibly adapted to a variety of issues and project realities. But SAS, as designed today, does not always seem to utilize its full potential. That is why I propose to test a variant, namely 'CIBAS' (CIB And Simulation) to build on its strengths and to moderate its weaknesses.

3 ‘Cross-Impact Balance analysis And Simulation’ (CIBAS)

3.1 Cross-impact balance analysis

Cross-impact balance analysis (CIB) (Weimer-Jehle 2006) is a qualitative form of cross-impact analysis (cf. Gordon/Hayward 1968). The approach has been developed and tested since 2001.[1] CIB is a form of qualitative systems analysis that can be used to define and to analyze impact networks in a qualitative way. CIB can be used as a systematic scenario technique to determine consistent configurations of impact networks. Until now, CIB has been applied as a qualitative scenario technique in various fields as energy, sustainability, innovation and health prevention[2]. The approach is based on concepts of mathematical systems theory (Weimer-Jehle 2006, 2008). Schematically, a CIB process consists in four steps:[3]

1. identify scenario factors (drivers)
2. define variants
3. assess their interactions
4. determine consistent scenarios

After having defined the ‘scenario field’ (i.e. the scenario goal, issue and scope), in the first step, relevant influences, i.e. scenario factors, are listed. These factors have to be defined and documented to assure transparency and a shared understanding by those involved into the process. In practice, 9 to 15 factors have been judged as a reasonable number.

In step two, for each factor, alternative future developments (‘variants’) are defined. These variants can be described qualitatively and/or quantitatively. Data of various scales can be used equally and jointly, i.e. nominal data (“red” or “green”), ordinal data (“strong”, “medium” or “weak”) as well as metric (numerical) data.

In step three, the interactions, i.e. the influences between the future developments, are considered. Therefore, all factors and variants are contrasted with all other factors and variants in form of a matrix (cf. the example ‘Somewhereland’ in figure 3). Possible reciprocal influences between the variants are discussed in a qualitative way: Every combination of two variants is discussed with regard to the question if there is a direct influence of the one development (in the row) on the other development (in the column). If an influence is seen as given, its direction (‘fostering or inhibiting influence?’) and its strength are assessed. A scale from -3 to +3 can be used, with 0 meaning ‘no influence’. This discussion has to be repeated for all the cells of the matrix, with exception of the cells on the diagonal. Note that indirect influences are explicitly excluded from the assessment, as they are represented automatically via the matrix as a whole. The impact assessments can either be based on literature review, expert interviews or on expert workshops where they undergo communicative validation. When the matrix is completed, it represents an impact network of the system under study.

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[1] CIB has been developed at the Academy for Technology Assessment Baden Württemberg and at ZIRN, University of Stuttgart.

[2] For a comprehensive overview of issues and projects see www.cross-impact.de

[3] For a comprehensive description of CIB processes and procedures see ‘guidelines’ on www.cross-impact.de

figure 3: Example for a cross-impact balance matrix of the (fictitious) 'Somewhereland'

	G			FP			EP			DW		SC			V		
	p	e	s	cp	ri	cf	de	st	dy	ba	co	sp	te	ri	m	so	fa
government (G)																	
-"patriotic" (p)				-2	1	1	0	0	0	0	0	-2	1	1	0	0	0
-"economy first" (e)				2	1	-3	-2	-1	3	-2	2	0	0	0	2	-1	-1
-"social" (s)				0	0	0	0	2	-2	3	-3	2	-1	-1	-2	2	0
foreign policy (FP)																	
-cooperation (cp)	0	0	0				-2	1	1	0	0	0	0	0	0	0	0
-rivalry (ri)	0	0	0				0	1	-1	0	0	1	0	-1	0	0	0
-conflict (cf)	3	-1	-2				3	0	-3	0	0	3	-1	-2	-2	1	1
economic performance (EP)																	
-decreasing (de)	2	1	-3	0	0	0				-2	2	-3	1	2	0	0	0
-stagnant (st)	-1	2	-1	0	0	0				0	0	0	0	0	0	0	0
-dynamic (dy)	0	0	0	0	0	0				-2	2	3	-1	-2	0	0	0
distribution of wealth (DW)																	
-balanced (ba)	0	0	0	0	0	0	0	0	0			3	-1	-2	-2	1	1
-important contrasts (co)	0	-3	3	0	0	0	0	0	0			-3	1	2	2	-1	-1
social cohesion (SC)																	
-social peace (sp)	0	0	0	0	0	0	-2	-1	3	0	0				2	-1	-1
-tensions (te)	0	0	0	-1	0	1	1	1	-2	0	0				-1	0	1
-riots (ri)	2	-1	-1	-3	1	2	3	0	-3	0	0				-2	-1	3
values (V)																	
-merit (m)	0	3	-3	0	0	0	-3	0	3	-3	3	-2	1	1			
-solidarity (so)	1	-2	1	0	0	0	-1	2	-1	2	-2	2	-1	-1			
-family (fa)	0	0	0	0	0	0	-1	2	-1	1	-1	2	-1	-1			
		↓		↓					↓	↓		↓			↓		
balance	0	3	-3	2	1	-3	-9	-1	10	-7	7	4	-1	-3	2	-1	-1

In step four, consistent scenarios are determined. Scenarios are generated via bundles of variants, i.e. for each scenario one variant per factor is chosen. The theoretically possible number of different scenarios corresponds to the overall product of the number of variants of all factors. Normally, only a small number of these scenarios is meaningful and consistent. Therefore, with CIB, every theoretically possible scenario is tested with regard to its internal consistency. This test is based on the information on the impact relations between the factors that is 'stored' in the matrix. The consistency of every combination of variants, i.e. of each scenario, is determined via the influence balance of the impact network. Consistent scenarios are those combinations that are in accordance with the influence 'rules' of the impact network. Because of the number of possible combinations, the consistency test is done with the help of the scenario software *ScenarioWizard*[4]. But for single scenarios, it can easily be done with pen and paper, too (cf. figure 3):

a. Mark a 'test scenario' in the rows of the matrix, i.e. select one variant per factor (see the rows marked in grey in the example).

b. Sum up the impact assessments of every selected variant per row (see influence sums per variant in the 'balance' line at the bottom of the matrix).

c. Compare per factor, if the highest sum per row corresponds to the variant that has been assumed in the test scenario (marked by the arrows).

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[4] Freely available on http://www.cross-impact.de/english/CIB_e_LgI.htm

If there is no correspondence, as in the example for the factor 'distribution of wealth', the impact network contains arguments, *why* the variant assumed in the test scenario is not consistent, namely because in sum, there are stronger influences speaking for another variant. This check allows to interpret in a meaningful way, what reasons may exist against the consistency of a scenario. In the example, the government's economic orientation (-2), a dynamic economic development (-2) and a society oriented to merit (-3) overall provide strong arguments against the assumption of a balanced distribution of wealth.[5] In the example of 'Somewhereland', only 10 out of 486 possible scenarios are fully internally consistent.

Cross-impact balance analysis is a systematic, semi-formalized technique that shares basic assumptions with other qualitative forms of scenario techniques. But CIB differs from creative-narrative scenario techniques as e.g. intuitive logics mainly because of its systematic and transparent process (cf.).

table 2: Comparison of Intuitive Logics (IL) (Wack 1985) and CIB (Weimer-Jehle 2006), own assessments

	IL	**CIB**
understanding of the future	because of uncertainty and complexity, alternative futures are possible (forecast non suitable)	
scenario approach	qualitative	
type of scenario technique	creative-narrative/holistic	systematic-formalized/formative
typical participants	decision maker, stakeholder, experts and lay people	rather experts and stakeholder then lay people
identification of scenario factors and definition of alternative developments	varies from intuitive (and less transparent) to systematic	explicit, systematic, transparent
creation of scenarios (combination of alternative developments)	intuitive, creative (with detail and nuance)	systematic, comprehensive, transparent
selection of scenarios	intuitive	based on the criterion of internal consistency
temporal orientation	sequential or non-sequential	(rather) non-sequential

3.2 Some conceptual ideas on 'CIBAS'

CIBAS builds on the general concept and on the strengths of SAS in terms of representing uncertainty and qualitative knowledge by using a qualitative scenario technique and combining it with numerical models. In CIBAS, the qualitative scenario technique used is CIB. Due to the change of the qualitative scenario technique, CIBAS might be an approach for experts rather than a tool fostering the inclusion of lay people.

It might be possible to design CIBAS in multiple different ways. For instance, CIBAS could be designed in form of *'consistent context scenarios*' (cf. also Weimer-Jehle/Kosow 2011), i.e. CIB scenarios provide environmental models (as e.g. emission models or energy system models) with information on the 'outside world' in form of consistent, qualitative scenarios (e.g. on social, political and institutional contexts). These could be quantified and used as input parameter for simulation runs of the model (cf. figure 4). Other variants are thinkable that put stronger emphasis on the possibility to use CIB impact networks as 'conceptual models' not only of the social contexts but of entire coupled human-environmental systems that then could support the integration of interdisciplinary knowledge.

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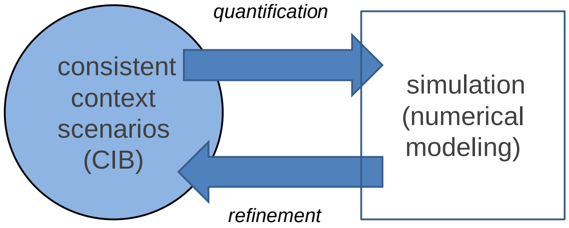
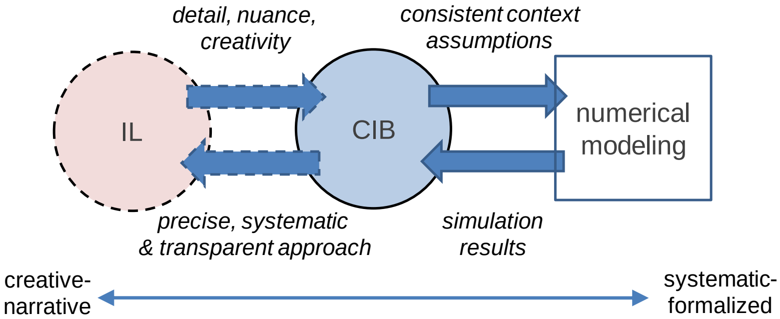
[5] Further forms of analysis possible with CIB are described in Weimer-Jehle 2006, Renn et al. 2009, the handbook of the software and on the methods' website.

figure 4: CIBAS designed in form of 'consistent context scenarios'



Note that theoretically, CIB could be applied either instead or in addition to IL (cf. figure 5). A combination of both scenario techniques could profit from the strengths of both. At the same time such an approach obviously would require considerable additional effort. Further research on possible variants of CIBAS is required.

figure 5: CIBAS using CIB in addition to Intuitive Logics (IL)



3.3 Expected potential and limits

First of all, CIBAS is expected to moderate the methodological imbalance between qualitative scenario technique and numerical modeling within SAS. CIB is a systematic and semi-formalized approach and it imperatively requires a transparent definition and documentation of scenario factors and future variants considered. The interrelations between developments are analyzed in a systematic way. Furthermore, all theoretically possible network constellations are systematically tested for their internal consistency. The balance algorithm is reliable and relatively easy to understand. Thus, CIB scenarios also offer an approach to select consistent context scenarios for numerical modeling in a systematic way. The choice of CIB instead of - or in addition to - intuitive logics might contribute to the scientific credibility of a SAS process as a whole because the method's systematic approach moderates some of the deficits of more creatively oriented scenario techniques.

Second, CIBAS is expected to support the reproducibility of the scenario process. This argument refers to the reproducibility of the *process*, not of the *results* in form of the scenarios. CIBAS would foster a transparent documentation of the process that should allow, at least in principle, to understand and to reproduce the decisions made. First, CIB requires systematic and explicit definition and documentation of scenario factors and variants. In addition, the assumptions on impacts between different scenario factors are documented in the impact network. Via a well documented CIB matrix, the mental models behind the scenario logics are made explicit. CIBAS could thus match the open requirement formulated by Alcamo (s. above). Visualizations of CIB matrices in form of graphs are possible and above all, these matrices allow for a variety of mathematical analyses. Overall, CIB networks might be more easily compatible with numerical modeling logics than mere narrative storylines.

Third, CIBAS is expected to carry through on the promise of consistency given by SAS. Within CIBAS, the internal consistency of the qualitative scenarios, understood as internal logic and freedom of contradictions, is assured by the CIB itself. The CIB logic forces to carefully analyze effects and interrelations between all different future developments. A comparison between qualitative and quantitative scenarios then still would allow for additional insight, e.g. to compare the assumptions made on interrelations in the two system models and to provide the qualitative storylines with indicators calculated by the models. But the CIB allows for a consistency check that a) includes qualitative dimensions that have no counterpart in a numerical model (modeling not possible or inappropriate) and b) allows for a *reciprocal* consistency check between qualitative and quantitative scenarios. In CIBAS, the CIB scenarios could be used as a conceptual model to reflect on the assumptions on interrelations made in the numerical models, too. Thus, within CIBAS, the qualitative scenarios provide a possibility to make the mental models behind both, the qualitative and the quantitative representations of the system more explicit.

CIBAS also might show specific limits. First of all, CIBAs might be ridden with many of the same prerequisites as SAS (cf. above). The quality of a CIBAS process, as of all scenario processes, strongly depends from the expertise and quality of the participating experts – and not only from the method applied. Furthermore, the transformation of verbal into numerical information remains a central challenge within CIBAS, too.

A further challenge of CIBAS might be a tendency to overemphasize causal relationships: Within CIB, interrelations between the developments of different scenario factors are interpreted pair wise as direct effects of one onto another. It might be necessary, when numerical model and storyline are compared and transformed into another, to be careful not to over-interpret the relations established in the matrix as (simple) cause-effect relationships. Further research is required with regard to this aspect.

These expectations on potential and limits of CIBAS suggest, that for internal *producer-users,* CIBAS could a) support the development of scenarios for exploratory goals with a higher scientific usefulness, and b) allow for effective interdisciplinary knowledge integration, because CIB as a form of conceptual modeling provides a meta-language for an interdisciplinary project team of experts allowing for ‘intra-project transparency’.

For external *recipient-users*, CIBAS could a) provide transparency with regard to the production of both, the storylines and the context assumptions of the numerical models; b) provide credibility by meeting higher scientific standards in form of a systematic and well documented approach; c) potentially provide more useful end-products that could also be used for scenario goals beyond scientific inquiry, as e.g. for information and/or decision support goals.

4 Conclusion

SAS processes reveal specific strengths as their approach to uncertainty and their ability to integrate qualitative information. My work suggests that their weaknesses could - in part - be counterbalanced by a new approach, namely by the combination of cross-impact balance analysis and simulation (‘CIBAS’). Mainly, CIBAS is expected to balance the methodological imbalance of SAS and to carry through on its ‘promise of consistency’. Overall, the expectations on strengths and limits of CIBAS suggest that it could enhance usefulness and credibility of SAS processes for internal as well as for external users.

Two central research needs remain. First, there is no consistent conceptual framework on combinations of qualitative and quantitative scenario approaches readily available that could guide the reflection of SAS variants. Thus, I will develop a more systematic grid discerning key features of process variants combined with a systematic typology of functions and users. Second, CIBAS in form of its different variants now has to be explored and tested empirically. Therefore, my colleagues and I currently initiate several case studies, e.g. on the topic of future water supply.

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