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Envisioning and probing the model for policy learning and scenario planning

Silvia Ulli-Beer [a,b)*], Birgit Kopainsky [c,d)], Ueli Haefeli [e)], Ruth Kaufmann-Hayoz [a)]

[a)] University of Berne, CH-3012 Berne, Switzerland
[b)] Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[c)] Swiss Federal Institute of Technology, CH-8092 Zurich, Switzerland
[d)] Flury&Giuliani GmbH, CH 8092 Zurich, Switzerland
[e)] Interface

* Corresponding author. Interfakultäre Koordinationsstelle für Allgemeine Ökologie (IKAÖ), University of Berne, CH-3012 Berne, Switzerland, Tel.: +41-31 631 39 71, e-mail: silvia.ulli-beer@ikaoe.unibe.ch

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Abstract

This paper describes the process of a combined system dynamics modeling and scenario planning approach. It empirically investigates how envisioning and probing system dynamic modeling has the potential to raise effectiveness of scenario planning for organizational learning and improved decision making. The approach is illustrated by means of a case study that was used to explore the influence of social trends on dynamic interactions between transport behavior and spatial development in Switzerland. In this case study a system dynamics model was developed that served as a communication tool for strategy development and for enhancing goal alignment between different policy sectors at the national level. A qualitative content analysis illustrates how comments from participants of group modeling workshops can be opened up as empirical indicators of stimuli for improved learning. Additionally, it gives empirical evidence that the chosen approach contributes to mitigating four drivers of unexpected decision failure as discriminated by Chermack (2004a): bounded rationality, the tendency to consider only exogenous variables, stickiness and friction of information and knowledge, and mental model with decision premises.

1 Introduction

This paper is about learning in the context of strategy development. The purpose of strategy development is to develop policies guiding personal behavior of individuals in an organization such that the total system achieves and maintains a good and unique fit with its ever-changing environment (van der Heijden 2005: 15). Learning, on the other hand, applies to the process whereby management teams change their shared mental models of their company, their markets, and their competitors (de Geus 1988). According Argyris and Schön (1996: 3) “organizational learning includes some informational content, a learning product; a learning process which consists in acquiring, processing and storing information; and a learner to whom the learning process is attributed.”

Institutional or organizational action must be based on a shared mental model in order to establish organizational continuity. Only through a process of conversation can elements of personal observation and thought be structured and embedded in the accepted and shared organizational theories-in-use. The conversational process needs to lead to increased alignment of ideas in order to activate organizational learning (van der Heijden 2005: 43f). There are several approaches to inducing this conversational process. According to van der Heijden (2005: 16), the study of scenario-based planning is the study of learning and invention. Similarly, in system dynamics group model building, the various actors in an organization or community combine their knowledge and mental models for the purpose of mutual learning (Zagonel 2002).

This paper contributes to scenario planning approaches by combining system dynamics modeling with scenario techniques as proposed by Kahn and Wiener (1971) and further developed by de Geus (1988), van der Heijden (2005) and Chermack (2004a) to name just a few. As learning is a prerequisite for effective strategy development we analyze how scenario planning and system dynamics group model building can be assessed in terms of learning stimuli. We apply the combined approach and the pragmatic assessment methodology to a case study in public policy.

The study’s objective was to explore the influence of social trends on dynamic interactions between transport behavior and spatial development in Switzerland (Ulli-Beer, Haefeli, et al. 2005). The modeling effort also aimed at informing strategy development and enhancing goal alignment between different policy sectors at the national level. Therefore system dynamics modeling was used to enhance a common system understanding between decision makers (Richardson and Pugh 1981, Vennix 1996, Andersen and Richardson 1997, Zagonel 2002). While considerable knowledge about normative objectives of sustainable transport has been elaborated there is a lack of knowledge about dynamic interactions between transport demand, societal trends, and spatial development. The study therefore aimed at closing the identified knowledge gap as well as at enabling institutional learning in strategy design. The elaborated dynamic simulation model specifically served as a communication tool and an analytical framework for scenario analysis.

The literature on scenario planning often focuses on the utility of scenario building for planning. However, this paper emphasizes the role of “group” model building and scenario planning for bringing together fragmented knowledge that is mainly captured in diverse reports and databases as well as unequally shared between an interdisciplinary team within the government.

Consequently, the objective is to illustrate how system dynamics modeling can enrich scenario technique approaches in the context of scenario planning. Limited human cognitive skills for coping with complexity are one important reason for applying simulation models for improved decision making (e.g. Dörner1980, Brehmer 1992). By applying system dynamics modeling this paper specifically aims at clarifying the conceptual link between scenario planning and organizational decision making as postulated by Chermack (2004a). Typical kinds of insights that can be gained by this system dynamics based scenario technique approach are illustrated. Main challenges will be pointed out that should be addressed in further applied scenario planning studies.

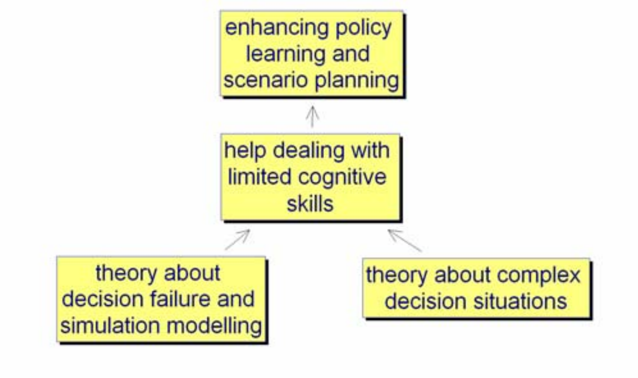

Figure1: Theoretical underpinning of the combined system dynamics modeling and scenario planning approach

Section 2 gives a brief overview over Group Model Building and learning while section 3 and 4 introduces the link between scenario planning, decision making and learning. Section 5 gives the theoretical basis for the rational of measuring learning stimuli from the combined system dynamics and scenario planning approach. In the subsequent section 6, computer assisted theory building that allows communicating and aligning mental models about system structure and behavior at first and subsequently about possible alternative futures will be discussed for our case study application. A content analytic process for detecting indicators of specific learning stimuli for improved system understanding is described. In the conclusions, it is discussed whether the approach has the potential to overcome the major problems in decision making identified by Chermack (2005) and summarizes the main insights about the contribution of system dynamics modeling in respect to improved decision making through scenario planning.

2 Group model building and learning

Simulation models are useful tools for exploring complex issues and negotiating an understanding of them. From this shared understanding, decision makers can work towards solutions that are better grounded in the organizational and socio-economic context (e.g. Senge and Sterman 1992, Repenning 2002, Zagonel 2003, Ulli-Beer et al. 2004) and so are more likely to be implemented successfully. Early on in the fields of system dynamics, involving the clients and the system experts in the process of model building was emphasized for different reasons: validation issues including the relevance of the model, implementation issues as well as issues on organizational learning (e.g. Forrester 1961,). Sterman 2000 highlights the various tools and techniques facilitating clients involvement such as causal loop diagrams, soft system techniques, policy structure diagrams as well as interactive computer mapping. As highlighted by Zagonel (2002) a line of research and practice exists that is termed Group Model Building referring to work done by Richardson, Andersen et al (1992), Richardson and Andersen (1995), Vennix (1996), Andersen, Richardson et al. (1997), Rouwette, Vennix et al. (2002). This research stream focuses on a theory about active client- and expert-group engagement, most importantly in the conceptual phase (see also Zagonel 2004).

Group Model Building has two inherent objectives: decision or process oriented objectives and policy or content oriented objectives.

> *"Decision or process oriented objectives in Group Model Building may be stated as accelerating a management team's work, problem structuring and classification schemes, generating commitment to a decision, creating a shared vision and promoting alignment, and creating agreement or building consensus about a policy or decision. Alternatively, policy or content oriented objectives may be stated as improving shared understanding regarding the system or problem at hand, system improvement, and system process and outcome change. These involve changing the mental models of individuals in the group or organization, guided by insights produced using the modeling tools and methods"* (Zagonel 2003:3).

Group Model Building interventions strive to create both a shared understanding of an interpersonal or inter-organizational problem in the form of a *boundary object* and a *micro-world* representing a model of the "reality" that is useful for policy analysis or organizational redesign (Zagonel 2002:43).

In this paper we build on both strengths of Group Model Building by combining system dynamics modeling and scenario planning. We applied group model building techniques in order to conceptualize, visualize as well as to probe the model – hence we used this approach for creating a boundary object. The theory also suggests that the study design for involving the client and system experts and its implementation is crucial for enabling organizational learning on the basis of a boundary object.

Subsequently, we used the simulation model as a micro world for scenario analysis. Hence the paper illustrates how group model building theory and practice can fertilize scenario planning and learning. It shows how it was actually done and discusses the immediate reactions of the audience.

3 Scenario planning and learning

Scenarios represent different possible future states of a system while scenario technique approaches involve the process of positing scenarios. Normally, two to three scenarios are developed. They should cover the extreme values of possible development trajectories and a status quo scenario that extrapolates system behavior of the past into the future (Lombriser and Abplanalp 1998). Apart from being small in number, the scenarios have to be consistent and significantly different from each other (Tietje 2005). Scenarios are good if they are relevant to the concerns of the decision makers. They also have to challenge the existing assumptions and take them beyond what is currently believed to be plausible (Chermack and van der Merwe 2003). Scenario technique approaches consist of several scenario development steps that are summarized in Table 1.

Table 1:Steps in the development of scenarios (adapted from Lombriser and Abplanalp 1998: 128)

Scenario development step	Questions to be asked for the completion of the step
1. Define and structure the problem	Define the conceptual and temporal system boundary.
2. Identify key factors	Which factors affect the system and how are they interconnected?
3. Identify the drivers of key factors	Which trends in the system's environment influence the development of the key factors? Which trends are predetermined and which are uncertain?
4. Classify drivers and key factors according to relevance and uncertainty	The relevant and uncertain trends constitute the scenario variables. The scenarios will differ from each other in the specific values of their scenario variables.
5. Describe future states for the scenario variables	How can scenario variables develop in the future? Worst-case, best-case, most probable case values.
6. Combine scenario variables into scenarios	Which combinations of scenario variables generate consistent and logical projections of future system states?
7. Choose and interpret main scenarios	Which main scenarios cover the possible development space of the system? The scenarios are formulated as stories about future system states.
8. Derive opportunities and threats for the organization	How do the policies in the system affect system behavior in the different scenarios?
9. Estimate consequences of possible system disruptions	How can disruptions affect system behavior? How robust are the scenarios to system disruptions? Which preventive measures and policies have to be planned for such events?

While the roots of scenario technique approaches are in futurology (Kahn and Wiener 1967) and strategic planning in the context of warfare the recent literature is mainly situated in organizational planning. Scenarios are a means for reaching better decisions for long term planning. Their application in organizational decision making is therefore called scenario planning.

Within the scope of scenario planning, scenarios are developed for the purpose of learning, changing thinking or for testing executive decisions (van der Heijden 2005). Learning in this context applies to the process whereby management teams change their shared mental models of their company, their markets, and their competitors (de Geus 1988). According Argyris and Schön (1996: 3) "organizational learning includes some informational content, a learning product; a learning process which consists in acquiring, processing and storing information; and a learner to whom the learning process is attributed."

When the scenario process is successfully implemented in an organization it provokes a strategic conversation (van der Heijden 2005) that enables organizational learning, by shifting current assumptions in the minds of decision makers. This capacity to learn subsequently makes the organization more adaptable to change (Chermack and van der Merwe 2003).

Scenario planning can therefore help avoiding decision errors in complex processes (Chermack 2004a). One defining feature of scenario planning methods is that all approaches advocate a systems view of the organization (Chermack 2005). The link between scenario planning and decision making will be further explored in the next section.

A first conclusion concerning the contribution of system dynamics modeling to scenario planning can be drawn on the basis of this introductory section to scenario techniques and scenario planning. An analysis of the scenario development steps shows that system dynamics modeling can contribute to many of these steps. It provides a theory-guided approach to problem definition and to the identification of the key factors and their drivers. A quantitative and well validated simulation model adds significantly to the last two scenario development steps by offering a testable theory on the structure and behavior of the system. This is especially relevant because scenarios need to be able to withstand scrutiny and be based on a deep analysis and understanding of the processes that drive the future and the range of behavior these forces may display during the scenario period (Chermack and van der Merwe 2003).

4 Learning, decision-making and strategy development

Decision failures are inevitable. They either occur as a result of some random error or of unexpected decision errors. Chermack (2004a) distinguishes four core interrelated causes for unexpected decision errors: 1) bounded rationality, 2) the tendency to consider only exogenous variables, 3) stickiness and friction of information and knowledge, and 4) mental models with decision premises. Scenarios and scenario planning, according to Chermack (2004a) have the potential to address all four of these core causes of unexpected decision error.

Decisions are made in dynamic and increasingly rapidly changing environments. In these applied contexts, decisions differ from the traditional cognitive decisions studied by psychologists in the following four ways (Brehmer 1992 in Chermack 2004a):

1. There are a series of decisions rather than a single decision.
2. The decisions are interdependent. Current decisions constrain future decisions.
3. The environment changes autonomously and as a result of decisions made.
4. It is insufficient for the correct decisions to be made in the correct order. They must also be made at a precise moment in real time.

These criteria reflect the complex and dynamic nature of the environment within which decisions must occur. The conceptual model displayed in Figure illustrates how scenario planning addresses the interrelated causes of decision error and failure within a dynamic decision making context.

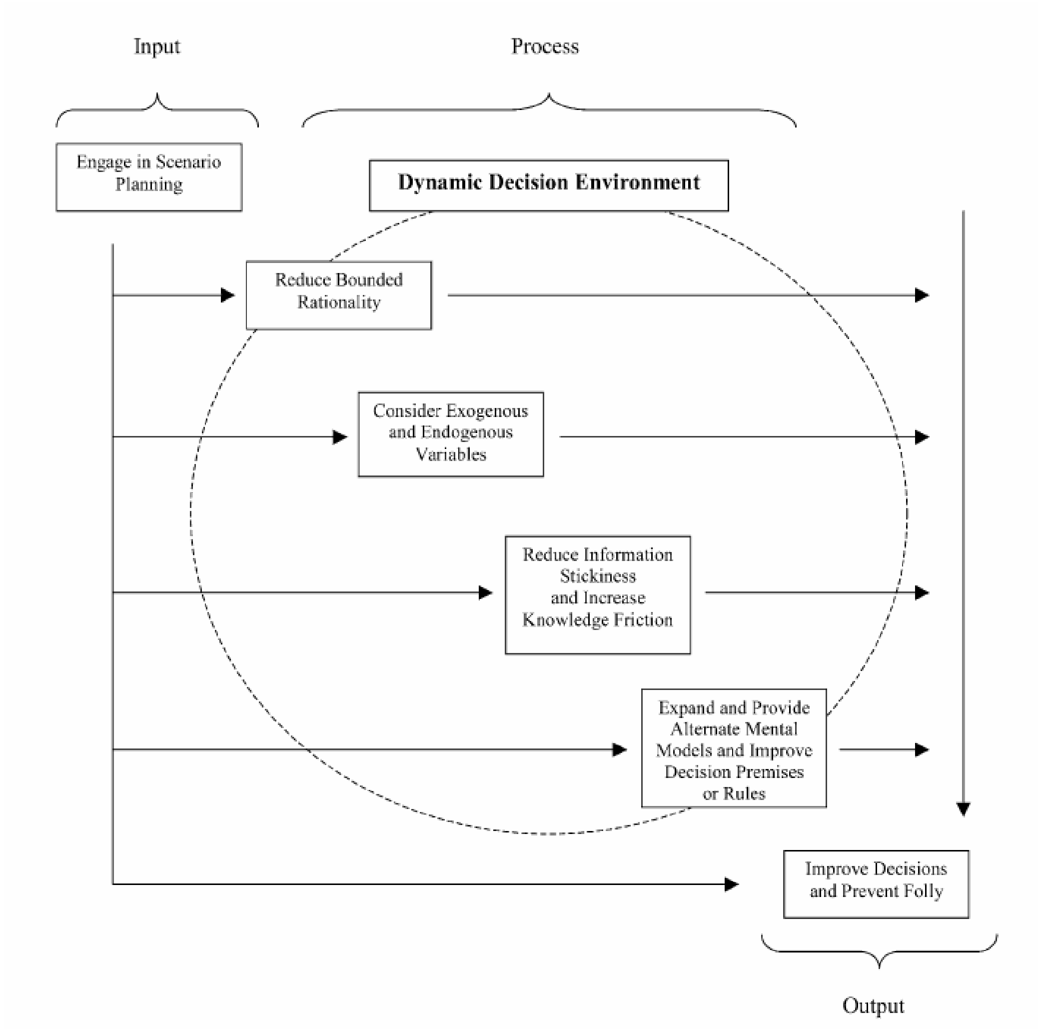

Figure 2: Conceptual model of improved decision making through scenario planning (Chermack 2004a: 297)

According to Chermack (2004a) scenario planning improves dynamic decision making in the following ways:

- Bounded rationality, defined as severe limitations on the information processing and computing abilities of human decision makers (Morecroft 1985), can never be completely extinguished. Scenarios, however, can address the issue of bounded rationality by providing relevant information in a format that is easily accessible from memory.

- Scenario planning emphasizes system structure and patterns that underlie events, thus it forces decision makers to consider both exogenous and endogenous variables. Internal variables that become inputs to organizational processes are often prioritized and highlighted in analyses of the organization's environment.

- A core aim of scenario planning is to alter the mental models of managers and decision makers. In doing so, scenario planning provides an increased capacity for individuals and groups in organizations to comprehend their environment.
- Scenario planning addresses the issues of stickiness and friction of information and knowledge. Scenario planning decreases the stickiness of information by providing a forum for several individuals to engage in learning that can lead to shared understanding. Scenario planning increases friction by relying on social and group interactions to consider problems and potential solutions from multiple perspectives and multiple mental models.

By preventing or reducing the impact of these core causes of unexpected decision failure, scenario planning in the context of decision-making processes aims at preventing folly and contributing to more effective decision making capabilities. A theoretical model of scenario planning (Chermack 2004b) therefore explicitly includes the following units: 1) scenarios, 2) learning, 3) mental models, 4) decisions, and 5) performance.

Based on these comments additional conclusions concerning the contribution of system dynamics modeling to scenario planning can be drawn. There is a considerable body of system dynamics literature addressing the issue of bounded rationality and the contribution of dynamic modeling to dealing with perspectives on rationality (for an overview see e.g. Grössler et al. 2004). With the endogenous point of view of the modeling approach, the causes of system behavior are contained within the structure of the system itself. System dynamics modeling therefore explicitly forces decision makers to identify system structure and patterns that underlie events.

Enhanced learning is not only based on scenarios but to an important degree also on system understanding. System understanding provides the basis for adjusting the existing mental models and therefore for improving decisions and policy performance. By providing a dynamic theory on the structure and behavior of the problem system dynamics adds an important element to the theoretical model of scenario planning.

5 Assessment of learning in strategy development

Till now we mainly layed out the basic theoretical underpinning of the combined system dynamic modeling and scenario planning approach. While these theoretical considerations provide the rationale for the effectiveness of the chosen approach we are also interested in understanding empirical effectiveness-indicators. In their literature review about group model building effectiveness Rouwette et al. 2002 found many different assessment approaches and results. They argue that the lack of integrative conceptual frameworks that link modeling practice to modeling outcomes makes an accumulation of research result difficult and inhibits a systematic evaluation of best practice elements. Therefore they suggested a conceptual framework that helps to understand different components of group model building effectiveness and serves as a basis for a theoretical grounded assessment instrument (Rouwette and Vennix 2003). In their conceptual framework they distinguish between context, mechanics and outcomes of Group Model Building efforts. Outcome variables are situated on four levels: the individual, the group, the organization as well as the method level. These dependent variables are mainly influenced by contextual and mechanical factors. The application of this assessment tool showed first promising but also diverse results in relation to the outcome of the Group Model Building effort. The study also showed the need for in-depth analyses of “context-mechanisms-outcome” configurations in order to disentangle the intervention from organizational surroundings.

In our case we explore a pragmatic way to disentangle the intervention from its organizational surroundings. This is important because the learning process (outcome) is strongly influenced by the mechanics (the detailed script) of the intervention. Hence for understanding improved learning both the scripts of the modeling workshops as well as the immediate reactions of the participants are decisive elements for evaluating group modeling intervention. This may help to identify and compare theoretically founded script-elements that are especially promising for improved decision making. Although this approach may not compensate sound effectiveness studies it may contribute to a profound understanding of some crucial intervention elements.

Based on these considerations the case study described in the next sections provides empirical underpinning of the conceptual model about scenario planning and decision making described in section 4. It also lays out the applied scripts that helps link the observed reactions of the participants to the workshop mechanisms. For analyzing the reactions the protocols of the two workshops will be analyzed.

The content analytic process will be mainly guided by the following four research questions:

1. What kind of questions and comments did emerge?
2. How were they related to:
    - the identification and understanding of the key factors and drivers as well as system indicators?
    - the understanding of model structure and behavior?
    - the understanding of processes that drive the future and the range of behavior these forces may display (visualization of system understanding as basis for adjusting system understanding)?
3. How were they related to improved decision making concerning
    - reduced bounded rationality?
    - considering exogenous and endogenous variables?
    - reducing information stickiness and increasing knowledge frictions?
    - expanding and providing alternate mental models and improving decision premises?
    - improving decisions and preventing folly?
4. How were the comments triggered by the mechanics?

6 Modeling for strategy development: Societal trends and dynamics between transport and spatial development

In this section the case study is described. Since the focus of this paper is on the applied method and on the process of scenario planning, the main results of the case study will only be mentioned as far as they illustrate characteristics of the insights gained by the chosen approach. For the whole documentation of the case study see Ulli-Beer, Haefeli et al. (2005).

6.1 Issues

The Swiss national transport policy aims at developing a transport system that is in line with the postulate of sustainable development (UVEK 2001; UVEK 2003), (Schweizer Bundesrat 2002). The Swiss national spatial policy also heads toward this direction. Considerable knowledge about normative objectives of sustainable transport has been elaborated (EBP 1998; Maibach et al. 1999; Keller, Mauch et al. 2000; Meier 2000). However, there is lack of knowledge about the dynamic interactions between societal trends, transport needs, and spatial developments. The study aimed at filling the gap, enhancing organizational learning and supporting strategy development as well as enhancing goal alignment between different policy sectors.

The following questions were addressed:

1. What are the relevant and crucial social variables (describing social trends) that strongly influence transport behavior and spatial development?
2. What social trends can be identified? What is their likely development?
3. What dynamical interactions exist between variables describing transport behavior and spatial development as well as social trends?
4. What are possible behavior modes of indicators of transport and spatial development variables under different social trend scenarios?
5. What kind of processes can be identified that are working towards or against the formulated normative objectives?

6.2 Project Design and Method

The design of the case study was adjusted according the collaboration culture between public authorities and researchers or consultants, respectively. Several meetings with the principals were held (see figure 2 briefing and debriefing meetings), in which the project progress, and next steps, as well as draft versions of the report documenting emerging results were discussed. This ensured first that the overall investigation was tackling the relevant issues and second that the principals could keep up with the project results. In addition the principals could provide the project team with relevant project reports and statistically evaluated data-input for the model from their empirical database.

In addition, two workshops of about four hours were conducted. According to the theory of group model building (Andersen and Richardson 1997; Andersen, Richardson et al. 1997) a narrow collaboration with system experts who were at the same time the most important target group of the study was sought, specifically in the problem identification and model conceptualization phase (1st workshop in Figure 2) and in the scenario analysis phase (2nd workshop in Figure 2). Due to budget and time restrictions a closer collaboration was not possible. The participants were experts in the realm of spatial and transport planning including economists, and authorities from both realms. In the first workshop there were 16 participants and in the second there were 11 participants. In the subsequent section to this overview, these workshops will be described in more detail.

The model development process mainly followed the Integrative Systems Methodology (ISM) and System Dynamics modeling method (Andersen and Richardson 1980; Richardson and Pugh 1981; Schwaninger 1997; Sterman 2000). The posited simulation model was calibrated drawing on a rich database about spatial development and mobility in Switzerland (e.g. Simma 2003). Interwoven with the model building action thread was the scenario development thread that included a literature review about main societal trends affecting transportation and spatial development. These trends were the most important input-variables characterizing different consistent social trend-scenarios within preexisting socio-economic scenario environments developed by Shell (Shell Deutschland Oil 2004).

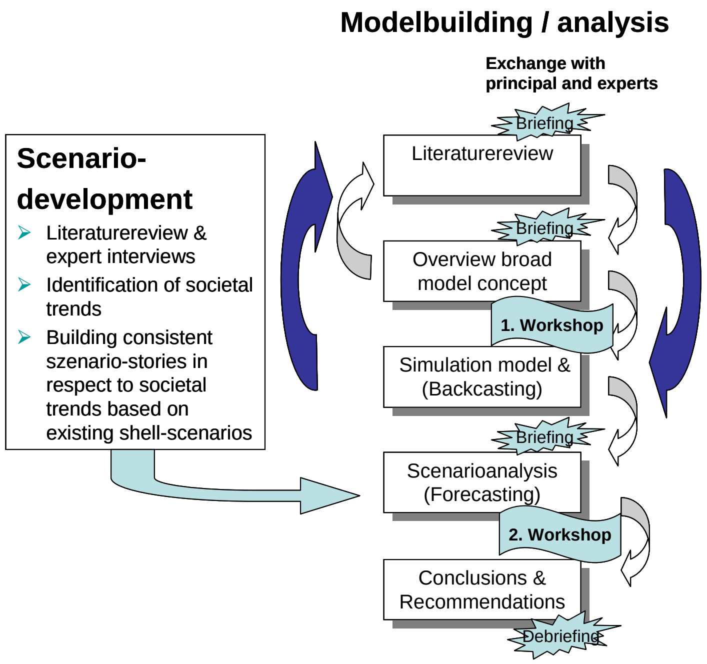

Figure 1: Case study design and applied methods

6.3 Scripts, inputs and products of the workshops

In the following section the scripts, inputs and products of the two workshops are outlined. This section provides important background information for understanding the results of the content analysis of statements that emerged in the course of the two workshops (section 6.3.1 and 6.3.2).

While this section presents the method and approach for conceptualizing, envisioning and probing the simulation model, later on the reaction from the workshop participants will be analyzed (section 6.4)1.

6.3.1 The first workshop – supporting and eliciting a feedback perspective on observed development trends with GMB-Techniques

The overall objective of the first workshop was to elicit the expertise of the participants in order to correct and to adjust the elaborated sub-system-diagram including a discussion of the identified social trends as well as the system indicators. Subsequently, the further course of action could be agreed on.

The challenge of the workshop was twofold. First, the participants had to get customized to a feedback perspective on transport and spatial development. Second, they were asked to apply an unknown analyzing method.

The first workshop was divided in four parts. Inputs from the project team were followed by plenum discussions or teamwork. For the workshop-design we were following the literature on group model building

Preparation of the workshop

In advance of the workshop the participants were provided with a report that included an overview of identified societal trends and a first sub-system-diagram. In addition to means of the "mass transit death spiral" - causal loop diagram developed by Sterman (2000), an introduction to causal loop diagrams (CLD) and its interpretation were given stressing the concept of policy resistance within a system.

The four workshop parts

First, visual representations of the concepts of black- and white-box models were given as an introduction to the discussion of the sub-system diagram.

Due to their professional background most participants were familiar with black box models and linear input – output scenario studies. Hence, the first part aimed at attuning the participants' perspective to a white-box model understanding and putting it in the context of the issue under consideration.

[1] The author team would like to thank Heidi Hofmann and Daniel Matti for their help in organizing the workshop and writing the protocols.

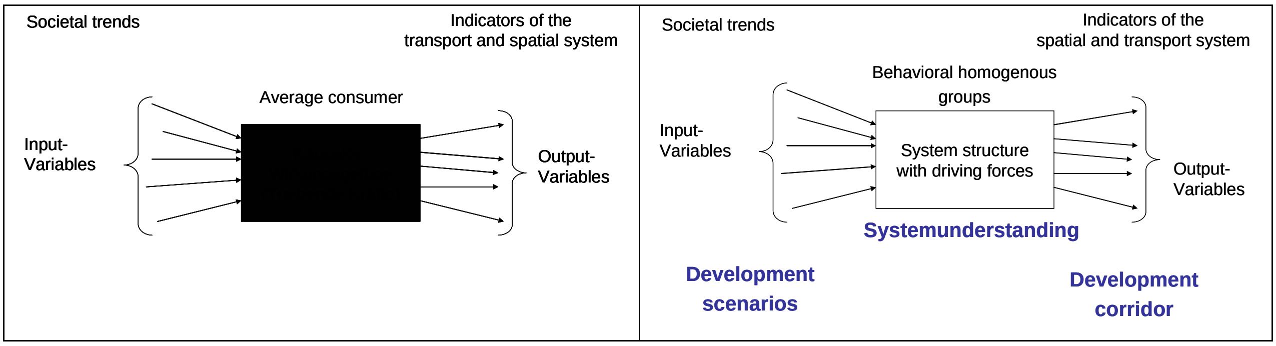

Figure 2: Comparison of „Black-box“ and White-box“ model approaches to scenario studies

Subsequently, the problem definition and the conceptual system boundary with its main system structure were presented in a sub-system diagram.

In accordance with the conceptual distinction between black-box and white box models, the sub-system diagram was first discussed as a black box model. For this purpose, the sub-system diagram box was covered with black paper. This allowed discussing the identified societal trends as drivers of important system indicators[2].

The participants were also invited to discuss the suggested system indicators. After uncovering the sub-system diagram box, the key factors of each sub-system were presented. The key factors illustrate the conceptual system boundary.

[2] The following societal trends were identified: Aging of the society, cohort effect in mobility behavior, increasing willingness to pay for mobility needs, decreasing household size, decreasing life working time, increasing flexibility in labor relations, gender equalization processes, raising risk-awareness concerning environmental problems.

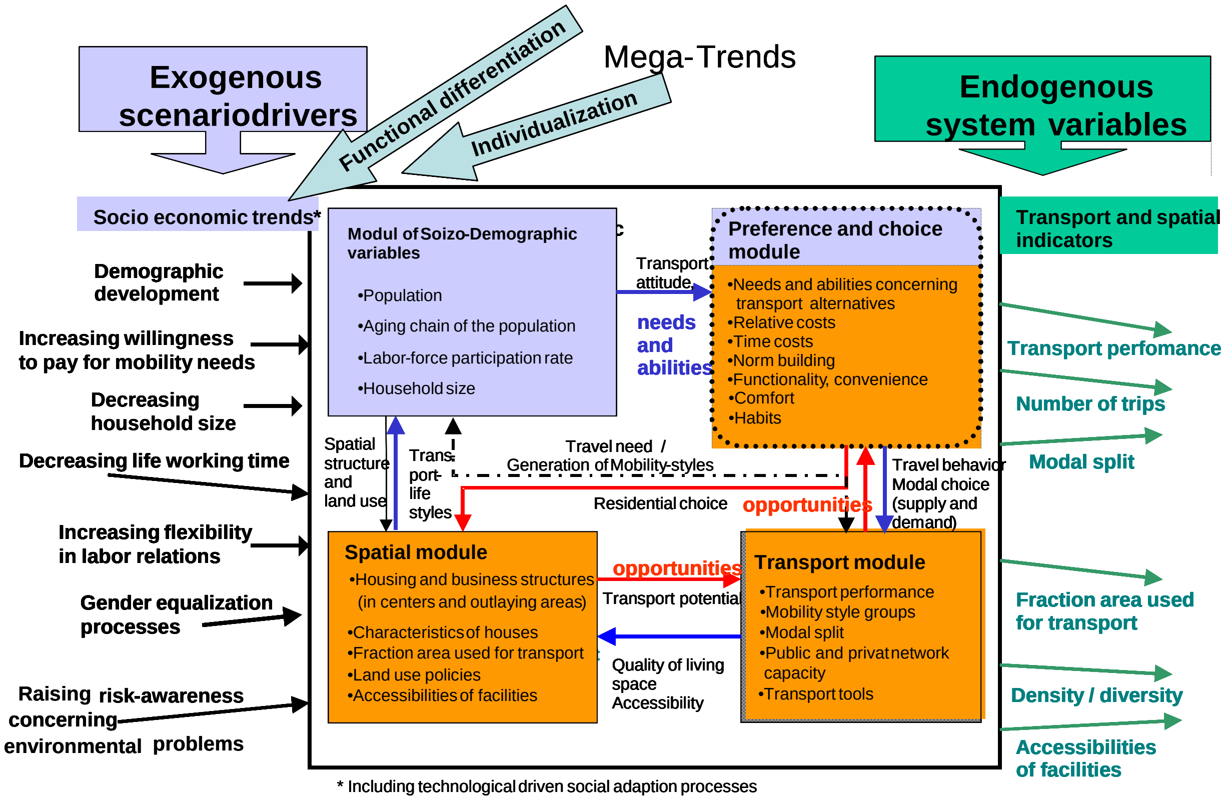

Figure 3: Sub-system-diagram

Second, the concept of key loops as causal agents and the notion of exogenous and endogenous variables were explained as drivers of observed developments trends. This input aimed at clarifying the difference between exogenous and endogenous system variables and illustrating the power of the endogenous point of view that allows focusing on dynamics over time between transport and spatial system variables (Figure 4). In addition, the conceptual tools for determining feedback polarity were explained.

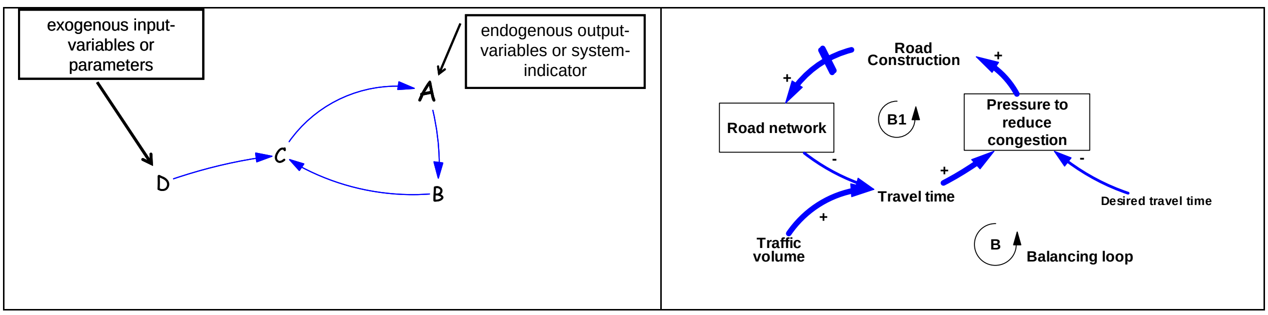

Figure 4: Conceptual tool for determining feedback polarity explaining behavior patterns of transport and spatial indicators

Subsequently the participants were asked to identify and discuss main factors that could explain observed behavior patterns of transport and spatial indicators. This task was accomplished in groups of three to four persons.

Third, four groups of participants were invited to create their dynamic hypothesis by means of a CLD that would explain the observed development of transport performance or urban sprawl.

On desk covering plastic sheets the groups drew their CLD. All proposed a dynamic hypothesis including at least two feedback loops. Each group gave their dynamic story a header such as urban sprawl or "Hüsli-Schwizer-Tüfelskreis"[3] and presented it to the plenum (see Figure 5).

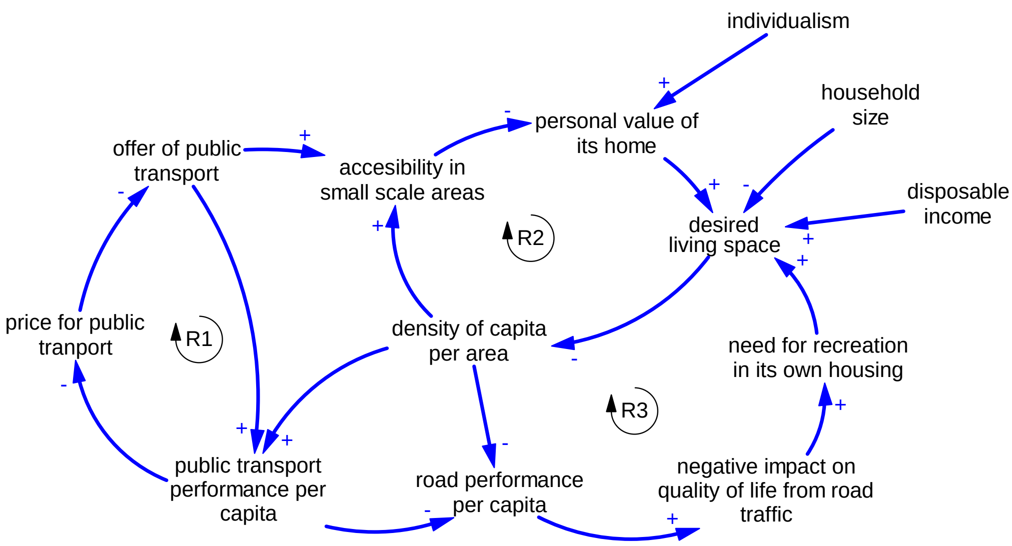

Figure 5: Example of a group's dynamic hypothesis explaining the development of transport performance on roads called "modal choice, density and living area"

Fourth, implications for the further model development and scenario building process were summarized and a follow up in a second workshop was agreed on. As a closing ceremonial each expert could give the project team a final advice for the further project development.

6.3.2 The second workshop – bringing together system understanding with scenario development and analysis

Five months after the first workshop, the same participants were invited to the second workshop. As agreed on with the principals, the workshop focused on discussing the simulation model structure in depth as well as on discussing the scenarios and the simulation results. The objective was to test the structure of the simulation model, especially its perceivability and plausibility. The

[3] Vicious circle of the Swiss "my home is my castle" mentality.

logic of the three proposed scenarios with the values of respective societal trends and the plausibility of the simulation results were also evaluated. Finally, implications were discussed. The workshop was arranged in two parts in accordance with the two foci.

Preparation of the workshop

Again the participants were provided with a full project report. The model structure and behavior was explained in detail as well as the adapted Shell-scenario-environments and the combination of plausible social trend variables to logic stories about possible future development were illuminated. The trigger points of social trends were highlighted and the report explained how the trends affect system behavior. First implications were drafted.

The two workshop parts

First, the discussion aimed at bringing about understanding of model structure and its behavioral consequences.

A highly aggregated model structure served as entry point to the discussion of the four identified theses about interactions between spatial and transport variables (research question two). Figure 6 presents the simplified model structure and the four postulated interactions. In groups of two persons they discussed the figure and especially the plausibility of the postulated theses.

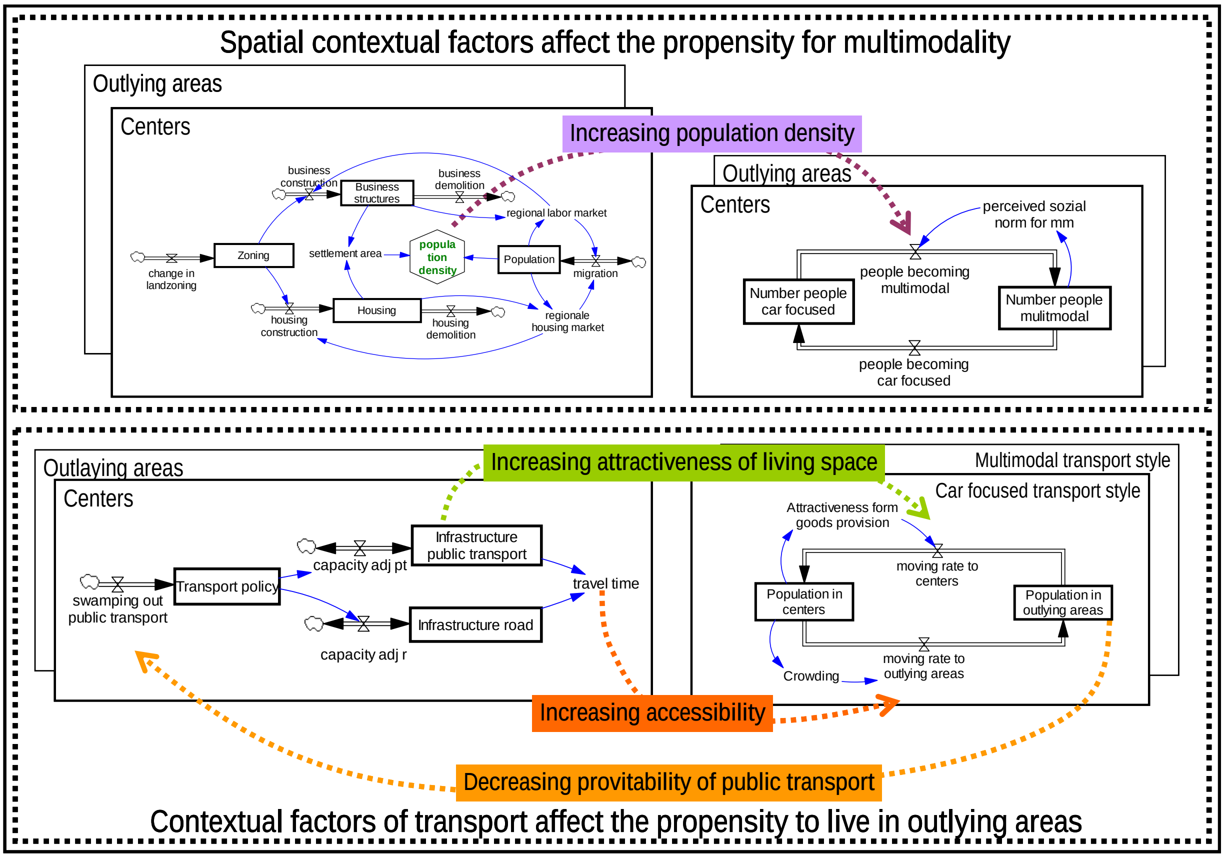

Figure 6: The main model parts with the identified four interactions between spatial and transport variables.

In a second step the model structure was presented and discussed in more detail focusing on most insightful causal relationships and variables that help reveal saturation effects and structures explaining limits to growth. For example, two simulation experiments were set up that demonstrated the behavioral consequences of a causal structure that described the diminishing negative effect of the increasing fraction of people with driving license on demand for public transport.

After the illustration of the behavioral consequences of the model structure and after showing the trigger points of social trends variables the participants were invited to discuss, in groups of two, the model structure controlling the moving rate to centers or outlaying areas respectively as well as the model structure controlling the number persons becoming car focused or multimodal respectively. This group work was only shortly discussed in plenum due to time problems.

Second, scenario development and analysis was discussed and understanding of the implications from the scenarios was increased. In the beginning of the second part of the workshop, conclusions on model quality and suitability for scenario analysis were presented.

Subsequently, the three scenario environments of the Shell study were discussed drafting three different visions of the state of the society in 2030. In a further step the combination of societal trend effects that are most plausible for the different visions were discussed.

Table 2 summarizes the numerical operationalization of the different scenario stories according to different effects of the identified societal trends.

Table 2:Overview of parameter chances within the different scenarios

Societal Trends	Trigger variable	Effect on trigger variable		
		Scenario Trend	Scenario Impulse	Scenario Tradition
Population development	*Migration and birth rate*	BFS, Scenario data Trend	BFS, Scenario data Increasing pop.	BFS, Scenario data decreasing pop
Aging of the society[1]	*Death rate*	A slight nonlinear decrease	A slight nonlinear decrease	A slight nonlinear decrease
- Increasing willingness to pay for mobility needs - Increasing flexibility in labor relations	*Transport performance*	1	Linear increase from 1 to 1.2	Linear decrease from 1 to 0.9
Decreasing life working time	*Transport performance*	1	Linear decrease from 1 to 0.9	Linear increase from 1 to 1.05
Decreasing household size	*Household size*	Nonlinear decrease from 2.2 to 2	Nonlinear decrease from 2.2 to 1.7	Nonlinear increase from 2.2 to 2.7
Gender equalization processes	*Min number of persons being multimodal*	Constant min number of persons being multimodal	Decreasing min number of persons being multimodal	Increasing min number of persons being multimodal
	Fraction of people having driving license	Nonlinear increase from 0.8 to 0.82	Nonlinear increase from 0.8 to 0.9	Staying constant 0.8

Raising risk-awareness concerning environmental problems	*Maximal willingness to pay for multimodal transport*	1	Linear increase from 1 to 1.1	Linear decrease from 1 to 0.9

[1] **Due to different population development the aging structure of the society will be different in each scenario even if the same slight decrease in the death rate is postulated**

Having discussed the scenario development and specification, the results of the different scenario simulation experiments were presented by means of Tables and in per cents for well defined time slices that were normally chosen in other scenario studies. This visualization rather than graphs over time were chosen, because the principals asked to do so and because it helped to avoid a discussion about the value of single point data. An example is shown in Table 3.

Table 3:Scenario simulation results for overall transport performance

Transport performance in sum	1970	2000	2020	2030
Trend	56%	100%	99%	97%
Impulse	56%	100%	121%	133%
Tradition	56%	100%	87%	78%

Subsequently the results and first conclusions were discussed in plenum. In a closing statement further model development directions and reflections on using the model as a learning tool were summarized.

6.4 Empirical evidence for stimuli of learning

The following analysis should help grasp what was going on in respect of learning during the workshop. What was the effect of the chosen workshop approach applying elements of group model building techniques? A qualitative content analysis method was chosen in order to better understand the meaning of the responses and statements of participants and to answer the first two research questions:

1. What kind of questions and comments did emerge?
2. How were they related to …
   - the identification and understanding of the key factors and drivers as well as system indicators?
   - the understanding of model structure and behavior
   - the understanding of processes that drive the future and the range of behavior these forces may display?

6.4.1 The content analytic process

In order to answer the first two research questions, the protocol of both workshops were analyzed. They include a summary of each statement (the statements were not documented literally). The content analytical process was carried out in two steps.

First the statements were classified according to the evolving steps in system dynamics model development. This classification resulted in the following eight different groups of statements that also reflect the issues addressed in the workshop:

Six statement categories from the first workshop

A Statements or questions concerning the specification of system drivers (social trends)

B Statements or questions concerning system and model boundary issues

C Statements of questions concerning identification and interpretation of system variables

D Statements or questions concerning specific model concepts

E Statements or questions concerning internal dynamics

F Statements or questions concerning utility and purpose of the model

Two statement categories from the second workshop

G Statements or questions concerning model representation

H Statements or questions concerning scenario building and analyzing

Second, each statement was analyzed in depth. The mere fact that a comment was made may be important for understanding the line of thinking of the participants. Each comment may have its own relation to an intangible mental model. Although it may be hard to reveal the reasons for the comment it is possible to question what consequences it may have for the learning process in the group. Indeed, each comment and question may become a stimulus for learning. Furthermore different comments may have specific functions for enhancing specific aspects in the course of model building and understanding. Hence, in the second step each comment was analyzed with respect to its potential function within a learning process.

6.4.2 The first workshop – empirical evidence of learning processes

The following presentation of empirical evidence of learning is based on the first workshop protocol including 35 statements that were coded. Table 4 gives a condensed overview of the six different classes of statements and the attribution of potential learning functions of comments belonging to the specific class.

The first column indicates the class to which the interpreted comments were attributed to. The second column specifies the potential learning function of the analyzed comments. The third column counts the number of statements that were coded.

Table 4: Different functions of comments regarding improved decision making in the discourse of system conceptualization

Classification of the comments	Function in relation to the learning process	N
A Statements or questions concerning the specification of system drivers (Social trends)	• Becoming aware of information limitations and uncertainty regarding the directions and strengths about driving forces • Becoming aware of uncertainty regarding the existence of a driving force and its assessment	3
B Statements or questions concerning system boundary issues	• Becoming aware of uncertainty regarding the definition of social trends as driving forces and its profile • Becoming aware of interactions between driving forces defined as exogenous variables and system endogenous variables • Uncertainty about the relevance of discussing endogenous variables in the process of forecasting and scenario development • Differentiating and defining exogenous and endogenous variables • Differentiating guiding system policies from exogenous policy intervention • Becoming clear about the issue of the analysis	7
• C Statements or questions concerning identification and interpretation of system variables	• Understanding different dimensions of endogenous variables and its relevance in respect of the issue under focus • Understanding different possibilities for operationalizing different factors and its interpretation • Understanding the conceptual meaning of variables • Understanding the level of aggregation • Becoming aware of potential information loss due to aggregation • Becoming aware of difficulties of operationalizing diffuse concepts such as accessibility • Understanding multiple explanatory power of a single factor • Identification of important explanatory variables • Reaching consensus about relevant system variables	13
D Statements or questions concerning specific model concepts	• Becoming aware of possible fallacies (action follows attitude) • Becoming aware of difficulties with multiple mobility style groups within a sd-model • Becoming aware of issues regarding the conceptualization of different spatial areas • Becoming aware of differences in focus on and aggregation of behavior discrimination • Becoming aware of limitations about the average consumer notion and its conceptualization • Understanding how policies are represented in the model concept • Becoming aware of limitation of developing a model and the trade off between parsimonious and highly disaggregated models • Becoming aware of the challenge of integrating soft and hard data within the simulation model • Understanding the necessity of reducing complexity and managing the expectation about the power of simulation results	10
E Statements or questions concerning internal	• Understanding feedback loops within the system and defining their polarity in a story telling approach	4

dynamics		
F Statements or questions concerning utility and purpose of the model	• Becoming aware of limitations regarding point estimates or quantitative results in general • Understanding the power of model building with respect to transparency of causal assumptions and increased system understanding • Stressing the importance of enhancing the understanding of the "mechanic" rather than stressing forecasting results	2

Based on the insights presented in Table 4 a first summary of the qualitative content analysis can be given. For each different type of statement according to system dynamic model conceptualization theory several functions in relation to the learning process have been identified. Although measuring a learning process within a workshop session is a very delicate issue this exploratory identification of different functions of comments in respect to improved decision making gives evidence that the applied group model building techniques offered ample stimuli for learning, already in the first phase of model development.

An interesting observation is, that the last advice given by the system experts for further project development was clearly related to the qualitative process criteria "improve decision and prevent folly" stressing the limitation but also the strength of using models for decision making. This also reflects the management rule coined by Conant and Ashby which states that the result of a management process cannot be better than the model on which it is based, except by chance (Conant and Ashby 1981) cited in (Schwaninger 2003a). This statement holds true both for mental and for simulation models. However, the different comments on the model developing process showed that understanding, creating and communicating a model has a lot to do with a clear understanding and interpretation of the model elements and its processes. Many comments showed that developing a consistent white box model for scenario development provokes many questions such as:

- How can this be defined?
- How should this be conceptualized?
- How can fragmented knowledge be consolidated within a model in a consistent way?

These kinds of uncertainties are neither revealed in black box models nor in mental. Traditional scenario technique approaches cannot deal with them either.

6.4.3 The second workshop – empirical evidence of learning processes

A short memory summarized the main comments made in the workshop. The single chunks of comments were analyzed by focusing again on the perceived function in relation to the learning process. Table 5 presents the results of the content analysis as described above.

Table 5: Different functions of comments in respect of improved decision making in the discourse of model representation and scenario building and analyzing

Classification of the comments	Function in relation to the learning process	N
G Statements or questions concerning the model representation	• Becoming clear what is not perceivable and traceable in the visualization of the background story of the model • Becoming clear that time-aspects can not be sufficiently visualized within a focused background story • Becoming aware about the difficulties of visualizing a simple background story of a complex system • Criticizing postulated causal assumption and phrasing alternative cohesions and causal assumptions • Phrasing further relevant causal assumptions that are missing in the visualization of the background story • Asking about a correct homomorphic mapping that captures the main mechanics and behavior sufficiently for the question at hand • Becoming aware that other interactions may be equally meaningful • Asking about the sensitivity and relevance of selected system variables • Understanding the conceptual mapping and its endogenous causal interactions	19
H Statements and comments concerning scenario building and analyzing	• Becoming clear what is not perceivable and understandable in the scenario descriptions • Criticizing counterintuitive behavior patterns and comparing these to other studies' findings • Comparing and criticizing behavioral patterns between scenarios and suggesting structural adjustment • Looking for structural explanation of counterintuitive behavior • Becoming clear what is not perceivable and understandable in respect to internal dynamic processes driven by external variables • Asking what are the relevant and sensitive scenario trends (system drivers?) • Comparing scenario results with ongoing policy debates and asking about inconsistency with reality • Detecting missing information about model documentation and testing • Becoming clear about the limitations for drawing conclusive policy implications	11

From Table 5 we can conclude first that this exploratory analysis of a system dynamics model discussion workshop highlighted further learning opportunities that were triggered by comments. These comments had assigned functions in relation to understanding dynamical complexity.

It is obvious that the identified functions evolved due to the explicit representation and discussion of the underlying scenario analyzing framework. In addition, they give evidence that a well visualized model is especially helpful in the process of scenario planning for several reasons:

- They stimulate thinking in causal relationships and to query behavioral consequences of model specification.
- Although it seems that all models are wrong, a well visualized model helps to stay focused in relation to the issue at hand and it helps to ask the relevant questions.
- Becoming aware of limitations of models and simulation results prevents folly in decision making.

7 Conclusions

This paper described the process of a combined system dynamics modeling and scenario planning approach. Its value with respect to improved decision making for scenario planning was discussed. For illustrative reasons we draw on a case study about dynamic interactions between transport behavior and spatial development in Switzerland that was developed in order to both enhance system understanding and enable institutional learning in strategy design.

The case study was subsequently used to provide qualitative evidence about the contribution of system dynamics modeling and scenario planning to avoid four sources of unexpected decision failure: bounded rationality; the tendency to consider only exogenous variables; stickiness and friction of information and knowledge; and mental models with decision premises. From this qualitative analysis, several conclusions can be drawn.

7.1 Empirical evidence to the conceptual link between scenario planning and decision making

The aim of this paper is to contribute to scenario planning approaches by combining system dynamics modeling with scenario techniques. The result of the exploratory content analytical process gives empirical evidence that the chosen approach provided ample stimuli for learning especially for model conceptualization and interpretation. Moreover the identified potential learning functions of comments shows that the chosen system dynamics approach to scenario planning explicitly stresses issues that

- provoke to consider exogenous and endogenous variable (e.g. in the process of differentiating and defining exogenous and endogenous variables),
- help reduce information stickiness and increase knowledge friction (e.g. in the process of criticizing counterintuitive behavior patterns and comparing these to other studies' findings),
- expand and provide alternate mental models and may improve decision premises or rules (e.g. in the process of understanding the power of model building with respect to the transparency of causal assumptions and to increased system understanding).

Finally there were clear statements that gave empirical evidence that becoming aware of limitations of models for deducing clear policy implications are important and that the understanding of the mechanics rather than stressing forecasting results may be more useful for improved decision making.

In sum the chosen system dynamics approach to scenario planning seems to fulfill important qualitative process criteria for improved decision making as suggested by Chermack (2004a). While some identified potential learning functions could be unambiguously assigned to one process criterion others seemed to contribute to more than one criterion (e.g. understanding different possibilities for operationalizing different factors and its interpretation). In addition we found that one important qualitative process criterion was to become aware of bounded rationality (e.g. becoming aware of information limitations and uncertainty regarding the directions and strength about driving forces). Many different functions contributed to reducing bounded rationality as well as to other identified process criteria.

We can conclude that the participatory system dynamics modeling approach to scenario planning offers many stimuli for

- learning about the strategy and strategic context of organization as well as
- the adjustment and alteration of mental models pertaining to the strategy and strategic context of the organization.

The content analytic approach of this study suggests that these stimuli can be measured by potential learning functions which the comments may have. In this way the comments can be opened up as empirical indicators of improved learning processes (see also Chermack 2005).

7.2 Reflections on links between modeling workshop-scripts, learning stimuli and effectiveness

The rather limited human cognitive skills for coping with complexity give one important rational for applying simulation model for improved decision making (e.g. Dörner1980, Brehmer 1992). Based on these evidences Chermack (2004a) deduced a conceptual model for improved decision making through scenario planning. In a separate research stream best practice approaches and a theoretical basis for group model building are worked on (e.g. Richardson and Andersen 1995). The effectiveness study by Rouwette and Vennix (2003) showed that many different factors influence the outcome of a group model building interventions, but it also stressed the importance of the "mechanics" of the intervention itself. The present work builds on all of these works and illustrates a pragmatic approach for evaluating learning stimuli offered by the study design. The measured stimuli of learning of this intervention are based on a simple stimuli-response model of learning widely discussed in behaviorism. Therefore it is plausible that the identified groups of statement reflect the issue addressed in the workshop. This gives evidence that designing a workshop based on a well elaborated group model building theory gives important guidelines not only for developing useful models but also for offering the right stimuli for improved learning in complex task. In addition not only the main modeling steps becomes important guiding principles but also the detailed scripts of the workshop. The scripts determine the concrete interactions with the workshop participants and hence the learning stimuli offered. This suggests that for improved learning in scenario planning studies a theoretical basis for script development and evaluation may become an important research task. This would also help to design simulation modeling studies as a qualified effective strategic conversation that helps improving and aligning the mental models of decision makers instead of mere adding to the machinery of prediction.

This study illustrated that System Dynamics and Group Model Building has to offer helpful guidelines also for scenario planning and that workshop scripts should be evaluated especially regarding its specific learning stimuli. According Skinner learning stimuli results only in behavior if they are reinforced – hence the effectiveness of such an intervention also depends on how often decision makers are confronted with such well designed decision support approaches.

Future research should address both the causal relationship between the script and measured learning stimuli offered in the course of modeling and scenario planning as well as organizational learning. Specifically, it should aim at identifying and measuring the drivers that improve the learning process and the quality of the decisions that result from the process.

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