COMPLEXITY IN FORESIGHT

Appendices

APPENDIX A PART 1, FRAMEWORK FOR SYNTHESIS

BACKGROUND

Abstract

This document provides a background to Appendices A.2 – A.7. Here four key notions are described. The concept of "learning-action networks" captures how informal linkages of people across institutional and organizational boundaries can influence change processes, and the critical role of these networks for environmental management and sustainable development. "Would-be worlds" are agent-based simulation models that function as laboratories and that can be used to generate thought experiments about possible realities remote from observable realities. The "Extended Learning Loop" is the the learning process that is enabled by experimentation with agent-based simulation models, and in which the results of the experiments provide hunches for new experiments. The "BLUEPRINT Criteria" are the set of five design principles that spell out how the Framework for Synthesis can tie all these ingredients together.

1. Introduction

The goal of INTERSECTIONS was to develop an agent-based simulation workbench that helps to achieve adaptiveness in strategic planning.

Along the project the viewpoint emerged that, in order to achieve such workbench, it was necessary to rethink the role(s) for modeling and simulation. According to that view, a number of modeling-related activities took place in close conjunction:

- new synthesis of theoretical ideas, inspired by concepts from the complexity sciences;
- application of multiple paradigms from system thinking, switching repeatedly from one paradigm to another;
- experimentation using a computer and agent-based simulation and/or other computational approaches;
- interdisciplinary interaction, involving "participatory" approaches.

A roadmap toward new modeling and simulation practices, as well as the designs of tools to support these practices, is elaborated in Chapters 2 through Chapter 4.

The first step along this roadmap, which is documented in full on the CD-ROM, has been to design, build and test an instrument that is applicable in practical situations. This instrument is a framework, called the "Framework for Synthesis", that is enabled by a set of tools. As a whole, the Framework and its toolset can be considered a precursor to a full-fledged workbench.

The main chapters on the CD-ROM (numbered 5 through 10) describe the ingredients of the Framework for Synthesis in detail. Here, in this background section, we take a step back and explain the Framework's principles along four key notions:

- learning-action networks (LANs);
- would-be worlds;
- the Extended Learning Loop;
- the BLUEPRINT criteria.

2. Learning-Action Networks

The Framework for Synthesis is designed to support learning-action networks.

Enhanced roles of informal linkages

A learning-action network (LAN) is a set of informal linkages that overlay and complement formal organizational structures to tie individuals together through a flow of knowledge, information and ideas (Clarke and Roome 1999). These authors identified a critical role for LANs in environmental management and sustainable development, both understood as processes that centre around complex series of continuously negotiated business and social projects or experiments.

The Framework for Synthesis aims to support LANs and the processes that they facilitate. This support is most effective when LANs embark upon efforts for strategic planning. Because the themes involved are always strongly interconnected, LANs need tools and guidance to quickly achieve fresh and integrated views. The Framework offers both tools and guidance, empowering individuals to collaboratively develop syntheses of their divergent perceptions of themes.

Challenges

From a perspective of creation and management of knowledge, the envisioned enhanced role of LANs is highly challenging:

- Those participating in LANs (experts, stakeholders) need to actively seek to cross the boundaries that separate them (institutional, organizational, disciplinary, language).
- Learning will not always preceed action. Instead, new syntheses are the result of a process of interaction of network participants in which learning (fragmented, multi-layered, unfinished) and action happen simultaneously (Roome 1997).
- While crossing boundaries and gaining new experiences, LAN-participants should somehow keep reference to the ongoing activity of identifying and evaluating strategic options.

Anchored creativity and structure

The Framework for Synthesis is designed to facilitate these interactive learning-action processes in a variety of possible contexts.

- The Framework provides a set of interconnected tools that push and sustain creativity, enabling LAN participants to mold their "blueprints for syntheses" into simulated experiments[1].
- The Framework provides structure through facilitation of the “Extended Learning Loop" that guides LAN participants to proceed systematically and make overall sense of their blueprints for syntheses, simulation models, experiments, etc. while developing a more fundamental understanding of themes, problems and strategic options.

Gaps are closed

The Framework for Synthesis is designed to close gaps that tend to hamper the interaction of science and policy-making:

- The Framework bridges the gap between, on the one hand, postmodern and complexity thinking about the study of social phenomena, and on the other hand, state-of-the-art modeling and simulation practices to support projects.
- With support of the Framework, LANs can take on their role as platforms for embracing contradictions and tensions that inherently arise due to the fundamental uncertainties[2] that obstruct problem-solving. LAN facilitators can let ensuing parallel voices from participants truly compete. These voices become more transparent and accessible because of their embodiment in computer-based experiments.
- Facilitators can also adapt better to a LAN's socio-cultural context. They are able to apply a loose approach based on working with blueprints for syntheses and less stiffened by the rigor of scientific research methods.

[1] Participants collaborate with a specialist modeling team.

3. Would-be Worlds: Laboratories Created on the Computer

The Framework's engines for creativity are "would-be worlds". They are simulation models created on the computer that function as laboratories.

It is concentrated on the particular kind of would-be worlds that are called agent-based simulation models. They are computer models allow populations of a great many virtual agents to make decisions and interact, with agents typically representing people or human organizations. As in real societies, systems of agents are capable of displaying highly complex dynamics which are very difficult or impossible to study with traditional modeling tools[3].

Would-be worlds allow to make new sense out of complex real-world dynamics through designing and conducting simulated experiments about virtual worlds. These simulations offer us an unconventional bottom up view on the real-world dynamics. Through experimentation we may stumble upon interesting ways of seeing large-scale complexity as a consequence of a few simple locally operating rules (hence "bottom up").

Simulations with agents

Requirements for working with agent-based simulation are few and hardly limiting:

- For designing experiments a modeling team needs to specify rules for how individual agents behave (e.g. how they move around, how they interact with other agents). These rules can be few and simple, using only little pieces of information about the agent world.
- Once the rules have been specified, the team can run a great number of simulations and observe the collective outcomes that are generated by the interactions of the agents. Some resemblance to phenomena in the real world would be desirable, requiring outputs that show some regularities (total chaos would not be very interesting).
- By repeating simulations, possibly with different starting situations and/or with different behavioural rules, the team learns more about the relationships between the actions of individual agents and the collective outcomes (provided that these relationships are tractable). This learning process helps in theorizing about the relationships between individual behaviours and collective outcomes in the real world.

Would-be Scenarios: “is” versus “would-be”

In conventional laboratory work the experimenter is typically a (team of) scientifically trained expert(s). And typically the goal of experimentation is to develop accurate mathematical descriptions of real phenomena.

However, in applications of would-be worlds, with support of the Framework for Synthesis, the experimenters are participants of a learning-action network. The participants are typically NOT trained in designing and conducting simulated experiments; instead they will work in collaboration with a specialist modeling team.

It must be emphasized that within the Framework for Synthesis the goal of simulation is NOT accuracy in the description or prediction of real phenomena, but rather to generate a rich diversity of possible instantiations of those phenomena each having the potential to become real, e.g. depending on choices regarding strategic options. In other words, the objective is to generate would-be scenarios (hence "would-be worlds").

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[2] These difficulties are illustrated by the continuing lack of consensus about basic theories to explain economic and social phenomena – despite their mathematical sophistication.

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4. The Extended Learning Loop

Throughout the Framework for Synthesis, creativity is anchored by making simulated experiments with would-be worlds part of the Extended Learning Loop. The Extended Learning Loop is an extension of the Traditional Learning Loop in modeling and simulation practices (see Figures 6 and 7).

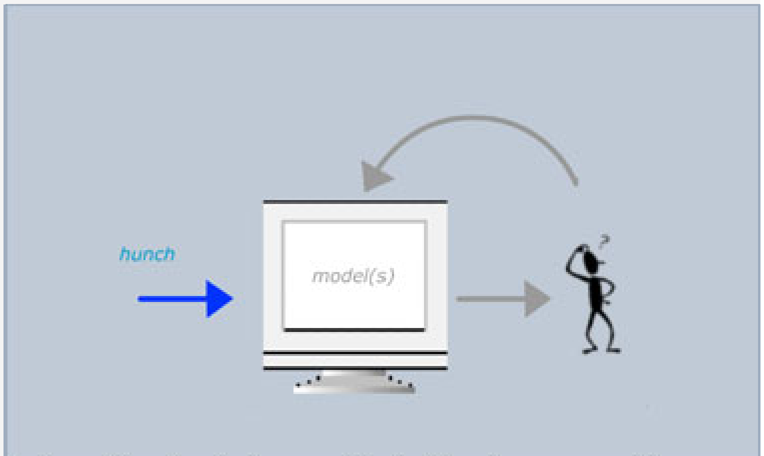
The Traditional Learning Loop

In traditional modeling and simulation practices models created on computers are merely instrumental in studying some target; i.e., a system or phenomenon of interest.

This traditional approach to modeling has several drawbacks:

- First, the learning based on these models is limited to those aspects of the target that can be expressed well by the model.
- Second, the obtained empirical data may constitute only a poor reflection of the actual target's behavioural repertoire.

Third, a very important drawback is that this kind of learning is very hard to communicate to others.



In the traditional learning loop a modeler's skills and energy are mainly concentrated on optimizing the match between the behaviour of the model and the target. modeling skills and experience are needed to make overall sense of several interconnected tasks: making tacit assumptions explicit so that they can be incorporated into the model, assessing whether the actual match between model and target remains sufficient, interpreting counter-intuitive results, and so on. Ideally the modeler gains growing confidence in the model along this modeling process and, once the modeler's confidence reaches a critical threshold, the study of the model will shift to other purposes (e.g. theory building, forecasting).

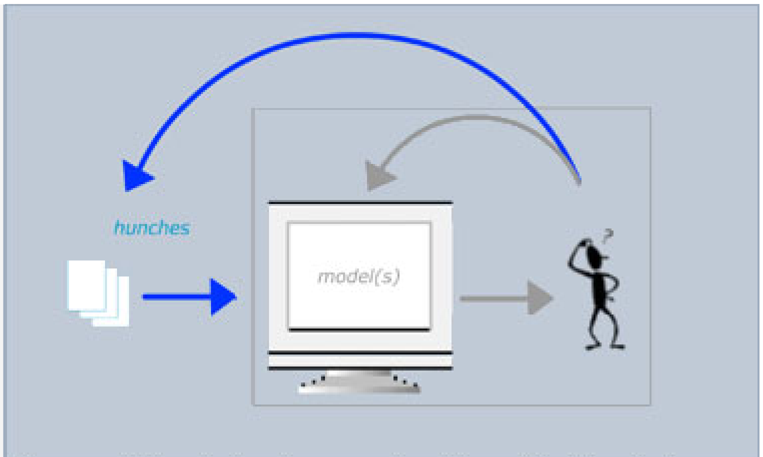
Figure 6 Traditional learning loop

The Extended Learning Loop

These drawbacks can be overcome by extending the traditional learning loop.

The Framework for Synthesis implements the extended learning loop lending a central role for simulated experiments with would-be worlds. These agent-based simulation models are not merely instrumental but entities "out there", by themselves worth of studying.

Their application within the Framework for Synthesis is an explorative endeavour, which is less steering for accuracy and more oriented toward fruitfulness. The modeling tasks are now distributed among the modeler and participants of a learning-action network, thus placing high value on continued interaction, learning and communication.



The extended learning loop is an extension of the traditional learning loop, possible because models are would-be worlds, by themselves worth of studying, rather than mere instruments. In short, the application of would-be worlds can be characterized by a flow from "hunches" to "blueprints for synthesis", then onward to simulation models and simulated experiments, and vice versa. Like in the traditional learning loop, there is learning about the behavioural repertoire of the model and the target through the study of experiments and empirical data. Additional learning occurs when experimentation leads to new hunches about further experiments. Now the skills and experiences of the people involved are needed to reflect on what the experiments tell about the "building blocks" that were originally chosen for the simulation model. Were they expressive enough in relation to the system or phenomenon of interest? Did they lead the modeling team to identify other building blocks that could help them conceive more fruitful experiments?

Figure 7 Extended learning loop

5. The BLUEPRINT Criteria

To effectively support learning-action networks, the Framework for Synthesis combines several ingredients into a coherent whole:

- People: LAN-participants, modeling teams;
- Ideas: hunches, blueprints for synthesis, simulated experiments;
- Tools: would-be worlds.

Design is critical: hów to combine these ingredients?

The BLUEPRINT Criteria

A lot of effort has been put in Framework for Synthesis' design for the optimal interaction of people, ideas and tools.

Based on a review of the state of the art in modeling practices, five requirements were distilled for the design of effective support for learning-action networks. These requirements are called the "BLUEPRINT Criteria" (Table 1).

Table 1 BLUEPRINT principles

BL	Back-loops (Reflexivity)	Inputs about relationships between high-level system components should be treated as parallel voices (not as absolute truths).
UE	Human/ environment	Human goal-seeking behaviour should be represented and non-measurable aspects should be taken into account.
PR	Problem-oriented	At some point, ends (goals, objectives) should be placed vis-à-vis means (strategies, measures).
INTg	Integrative	Modelling should integrate what is already there (science, models, expert opinions).
INTa	Interactive	Modelling should be quick, participatory and offer valuable scripts.

Beyond the state of the art

The results of the state of the art review (Table 2) show that current modeling and simulation practices to support projects embrace some of these principles, but not all. The Framework for Synthesis is designed to meet ALL five principles.

Table 2 Review of state of the art modelling and simulation practices against the BLUEPRINT principles

	BL	UE	PR	INTg	INTa
System Dynamics	No	No	Yes	Possible	Possible
Integrated Assessment	No	Possible	Yes	Yes	Possible
Visual Modelling Tools	Yes	No	Yes	No	No
Dynamic Actor Network Analysis	No	Yes	Yes	Yes	No
Rapid Assessment	No	No	Yes	Yes	Yes
Symbiotic Human/ Computer Modelling	Yes	No	No	Yes	Yes
Agent-Based Simulation	Possible	Possible	Possible	Possible	Possible
Framework for Synthesis	Possible	Possible	Yes	Yes	Yes

APPENDIX A PART 2, FRAMEWORK FOR SYNTHESIS

THE EXPERIMENTAL DESIGN FRAMEWORK

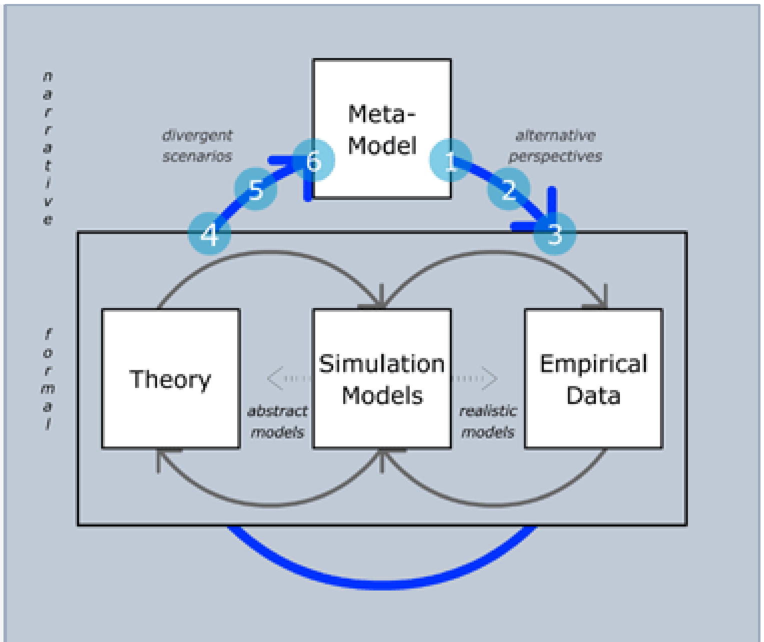
Abstract

A framework is proposed for designing experiments with agent-based simulation models. Six steps guide modeling teams in a creative process that is called the "systematic exploration of hunches". In this process, intuitive insights and reality-based observations flow freely along two learning loops. Along the "traditional learning loop", hunches are elaborated into simulated experiments and put to test. The "extended learning loop" takes hunches to the more abstract meta-level, where they are (re)viewed as small webs of inter-connected conceptual "building blocks" within a much larger web. The result of iterating over the six steps is a series of would-be scenarios that are supported by experimental data and meta-level knowledge.

1. Introduction

The Experimental Design is the design process for simulated experiments with agent-based simulation models. Six steps guide modeling teams in the design process:

- Step 1: Select building blocks;
- Step 2: Produce perspectives;
- Step 3: Define models;
- Step 4: Conduct experiments;
- Step 5: Produce scenarios;
- Step 6: Evaluate building blocks.



Six steps guide modeling teams in the process of designing experiments with agent-based simulation. These steps involves repeatedly switching from the narrative to the formalized (steps 2 and 3) and back (steps 4 and 5). The meta-model (steps 1 and 6) adds flexibility and creativity to the design process.

Figure 5.1 The Experimental Design: overview

The Systematic Exploration of Hunches

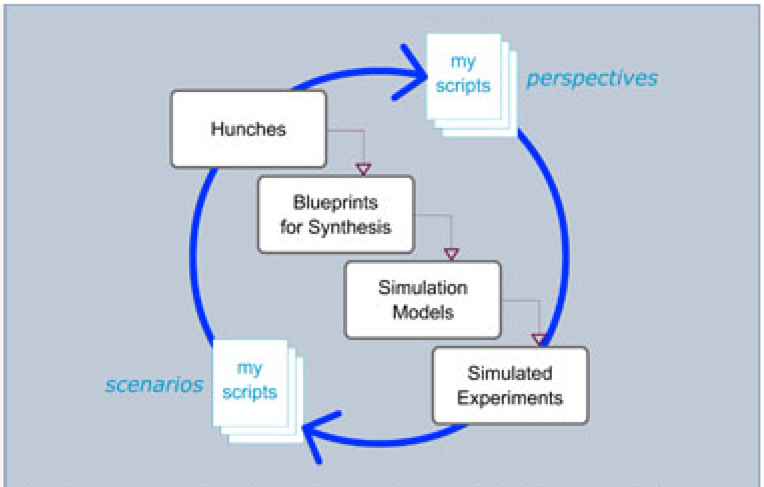
The six steps facilitate a process that is called the "systematic exploration of hunches" (see Figure 5.2, which is a simplified version of Figure 5.1).

It frequently happens that new hunches are provoked by the experiments. The use of building blocks enforces this learning loop. They are used to elaborated hunches into "blueprints for synthesis", so that new hunches can be (re-)considered not as substitutes but in connection with other possible syntheses of building blocks.

▸ New hunches can be generated by systematically exploring webs of building blocks (see A.3), hence the SYSTEMATIC exploration of hunches.

Would-be scenarios

Iterating over the six steps results in a series of "would-be scenarios" that are supported by experimental data and meta-level knowledge.



The Systematic Exploration of Hunches is a two-levelled process. Like in standard simulation practices, hunches are elaborated into experiments with simulation models and the behaviours of these models are systematically explored through analysis of experimental data. This flow is complemented by a second flow of ideas and insights on the meta-level. Hunches are elaborated into perspectives that are written in narrative style. The main results with simulations, the would-be scenarios, are also put into narrative. These written accounts help to critically assess what kind of questions can be addressed with the simulation models and what kind of answers these models can produce.

Figure 5.2 The Systematic Exploration of Hunches

Step 1: Select Building Blocks

In step 1 a web of building blocks is used that establishes a mapping of social theories. The web is comparable with a network graph and has between 50 and 100 building blocks. The web is systematically explored ("navigated") to identify promising combinations of building blocks and assemble them into coherent sets of between 5 to 10 building blocks.

- Building blocks are abstract representations of theories, syntheses, models, concepts or ideas. It is explained elsewhere how webs of building blocks are created and used. See A.3.

- Because one person is unlikely to know an entire web, selecting building blocks is best performed in an interactive workshop. See A.5.

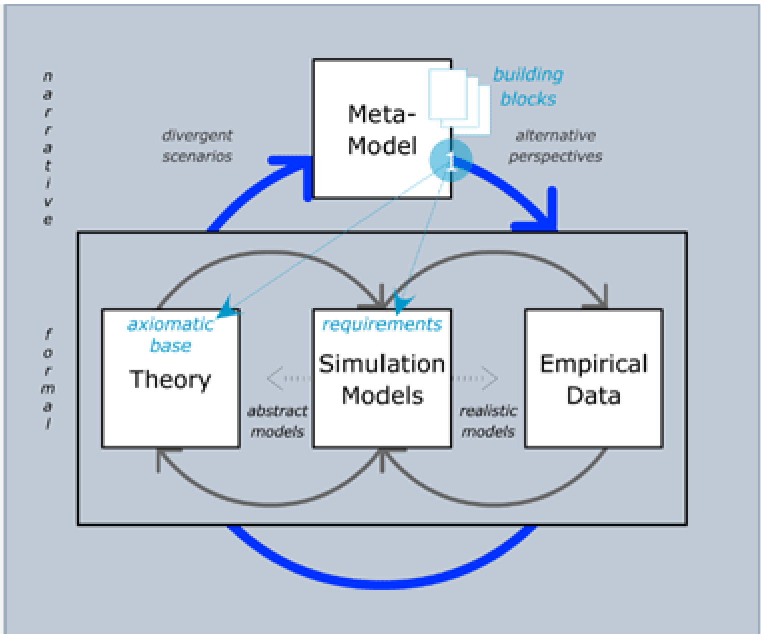
Axiomatic base

The selection of building blocks results in an axiomatic base that is comprised of "blueprints for synthesis". Because a web includes references to the theories, models, etc. that establish the inter-connections between building blocks, that knowledge becomes automatically part of the axiomatic base. A modeling team is free to add their own hypotheses about plausible interconnections, as long as they can be tested with simulated experiments.

Modeling requirements

Webs may also include information about the consequences of selecting building blocks in terms of requirements for agent-based implementation. The critical requirement that is imposed concerns the "minimal" agent type.

- The issues of modeling requirements and "minimal" agent type are addressed elsewhere. See A.4 and A.5.



Step 1 is concentrated on the selection of building blocks. Coherent sets of building blocks are assembled, picked from a web of between 50 and 100 building blocks. These coherent sets, called blueprints for synthesis, constitute an axiomatic base for agent-based modelling. They also spell out the requirements for agent-based implementation. Essential in this step is the way building blocks are selected. Well-documented "webs" of building blocks are used that can be navigated by a single person or, preferably, interactively by groups of people.

Figure 5.3 Step 1: Select building blocks

Step 2: Produce Perspectives

In step 2 the modeling teams produce alternative perspectives on the phenomena of interest. The perspectives are based on the building blocks that were selected in step 1.

Perspectives

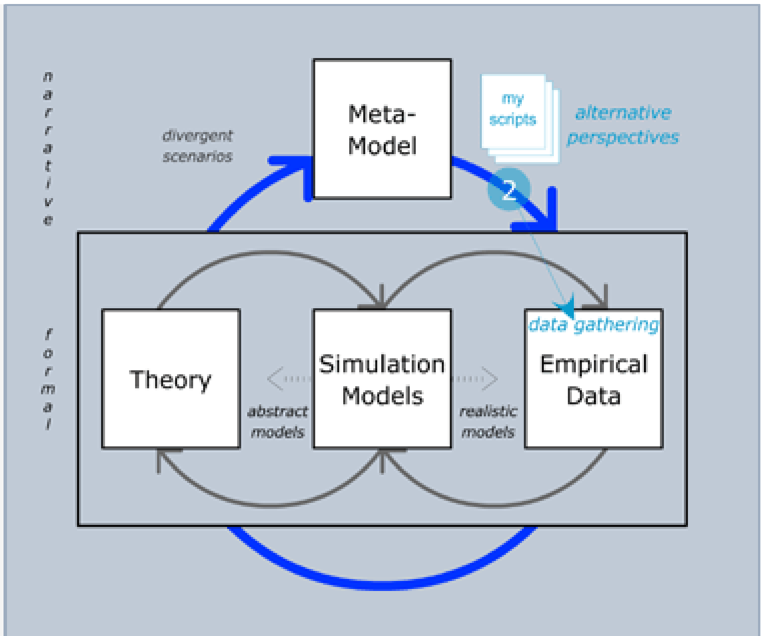
All perspectives are written in narrative style. They tell different stories about the (same or different) phenomena involved and the fundamental processes responsible for those phenomena. They also state a priori expectations about the kind of dynamics that can be observed in simulated experiments.

Valid scripts

Perspectives are very important for the design and study of simulated experiments because they indicate in an early stage what scripts[4] are valid. Early decisions about the validity of scripts will reduce the risk that the activity of implementing agent-based simulation models (step 3) becomes directionless. It should be clear in advance (to the extent possible) what kind of questions the model should be capable of addressing and what kind of answers it should be capable of producing.

Data collection

In order to produce accurate scripts it may be necessary to probe reality with data collection efforts. The building blocks selected in step 1 can help tailoring projects to gather critical data.



Step 2 is concentrated on the production of alternative perspectives. Perspectives are written accounts in narrative style. They are written in a format called "scripts". The concise script format helps bridge the gap between the narrative style of perspectives and the formal style used in experimentation with simulation models. The same script-format is used again when the results with experimentation are transcribed in narrative (step 5). Consequently, it is possible to compare two sets of scripts: a priori and a posteriori (this comparison is done in step 6). Besides scripts, perspectives can be used in this step to finetune projects for data collection.

Figure 5.4 Step 2: Produce perspectives

[4] Scripts help to carefully coordinate individual changes to the various interacting components of a simulation model, like agents.

Step 3: Define Models

In step 3 modeling teams define and implement agent-based simulation models for the perspectives that were produced in step 2.

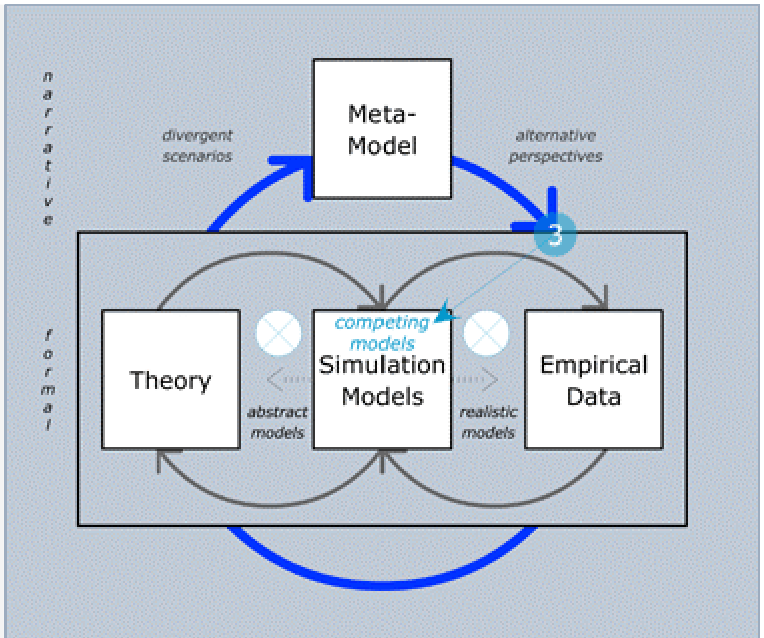
Competition of models

Models are thought of as being in competition with each other. For each perspective a specialist agent-based modeler defines and tries out models bilaterally with other teams or team members, who may have different disciplinary backgrounds. (For example, the specialist will work with an economist on a perspective that is economics oriented, with a geographer on a spatial dynamics view, etc.). The competition of models helps keep the modeling teams interested in exchanging their ideas.

Baseline models

The starting points for the definition of new models are the Baseline simulation models. The specialist agent-based modeler adds detail to the Baseline models, ideally by modifying its programming code only in specific parts. The amount of detail and modifications depend largely on which selection of building blocks underlies a perspective.

▸ Minimal requirements for model implementation were already estimated in step 1.



Step 3 is concentrated on the definition and implementation of agent-based simulation models. Modeling teams do not seek to build one model but multiple competing models, each representing a different amalgam of building blocks, perspectives and agent-based implementation. (In a way this extends the building-block approach to the entire experimentation cycle.) To fuel the competition, a specialist modeler works bilaterally with teams or team members (with possibly different disciplinary backgrounds). The Baseline models help to minimize overhead in terms of additional details and program modifications. (In early iterations over the six steps, the principle of competition of models is more important than leveraging a single model's usefulness).

Figure 5.5 Step 3: Define models

Step 4: Conduct Experiments

In step 4 experiments are conducted with the simulation models that were defined and implemented in step 3.

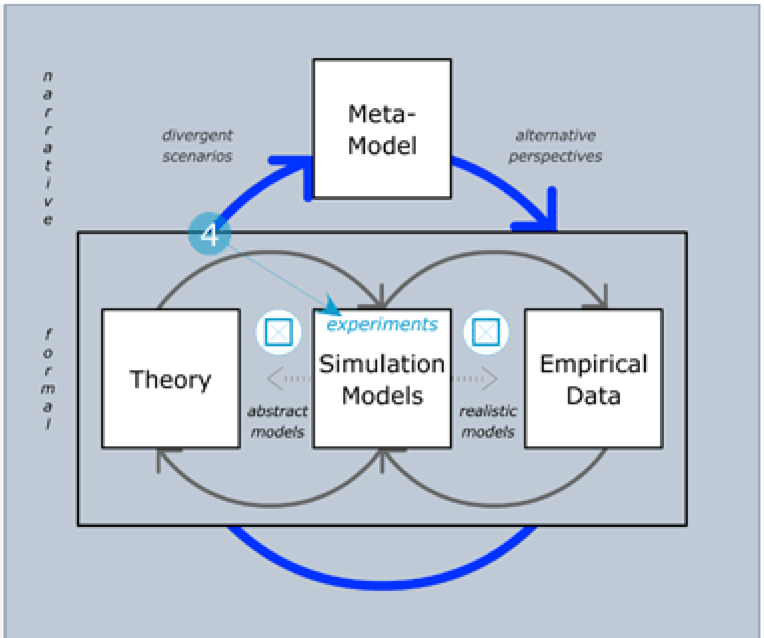
In each experiment the simulation model is run a large number of times (typically between 500 and 1000 trials). Because the greater part of the rules that drive the interactions between individual agents will be probabilistic, repeating a simulation in exactly the same circumstances can generate very different dynamics. Indeed in agent-based simulation it is common that initial conditions have big influence. Consequently, parameter sweeps will be necessary to avoid ill-based conclusions.

The experimental data that is obtained in this step should include:

- Runs that aim to reproduce valid scripts (already in step 2 decisions were made about valid scripts)
- Runs that serve to explore a model's sensitivity to initial conditions (e.g. for parameter sweeps)
- Runs that address major uncertainties from a scenarios point of view

Ideally, the essential insights offered by the experimental data can be captured by a small, coherent set of well-understood simulation runs, including a base scenario and a divergent set of would-be scenarios. The choices of these runs should be primarily inspired by the expectations that were stated in the perspectives and NOT by validity concerns.

These concerns play again an important role in step 6.



Step 4 is concentrated on conducting simulated experiments. Since a modelling team will measure its success by the fruitfulness of "would-be scenarios" rather than the accuracy of "as-is scenarios", validity concerns are not as prevalent as in traditional simulation studies. (It is highly recommended however to include a "base scenario" for proper interpretation of the simulation results.) The reason to concentrate on "would-be scenarios" is the high sensitivity to initial conditions that characterize almost all agent-based simulation models.

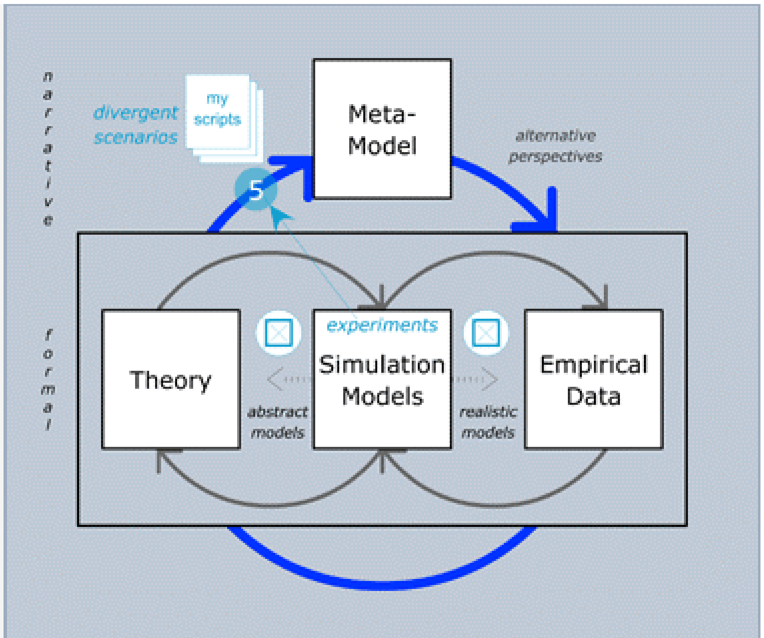
Figure 5.6 Step 4: Conduct experiments

Step 5: Produce Scenarios

In step 5 the would-be scenarios from step 4 (as well as the base scenario) are more broadly interpreted and put into narrative.

Details get inevitably lost when results of simulated experiments are "transcribed". It is therefore important that those written accounts include references to the simulation results. The script-format applied in step 2 helps state those references unambiguously. A posteriori scripts can be made more interesting by anticipating a comparison with the a priori expectations that were stated in step 2.

▸ The actual comparison of a priori and a posteriori scripts is done in step 6, when the entire flow from hunches to simulation results is reconsidered while concentrating on the meta-level.



Step 5 is concentrated on the production of "would-be scenarios", which should be underpinned by a "base scenario". Simulation results are more broadly interpreted than in step 4, keeping an eye on the a priori expectations that were formulated in step 2. A script-format - the same format as was used in step 2 - helps transcribe the essential meaning of simulation results in narrative style without letting the important details of the simulations disappear out of sight.

Figure 5.7 Step 5: Produce scenarios

Step 6: Evaluate Building Blocks

In step 6 the modeling teams reconsider the initial selections of building blocks in step 1. This activity is concentrated on the meta-level, i.e. the teams critically reflect on the entire flow from hunches to simulated experiments, and in particular the perspectives and would-be scenarios that were produced in steps 2 and 5, respectively (see Figure 5.8).

The evaluation leads to conclusions based on three possible cases:

- invalid scripts;
- irreproducible scripts;
- overlapping scripts.

Case: Invalid scripts

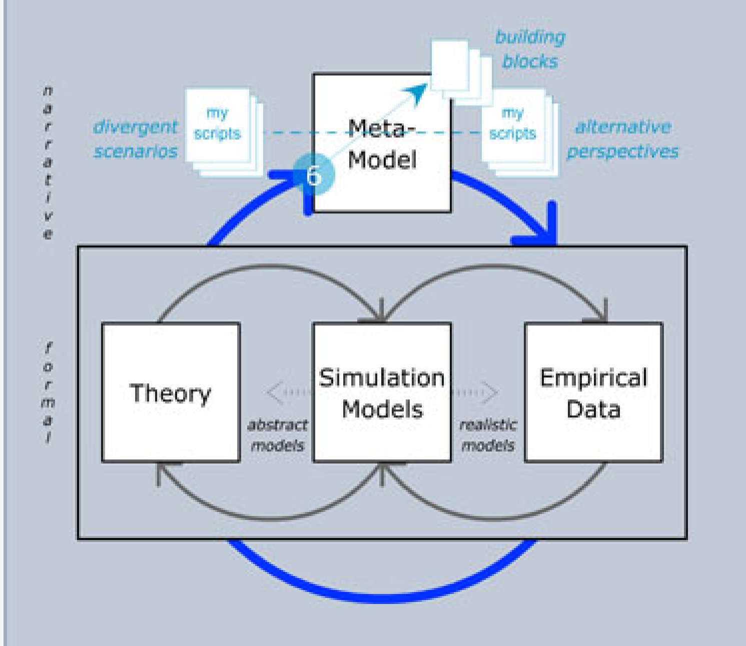
The experiments with simulation model have produced "invalid" scripts, urging the modeling teams to reconsider the model definitions and the experiments.

Case: Irreproducible scripts

The scripts that the modeling teams considered valid for a perspective cannot be reproduced with the simulation model. In this case, the teams have confidence in the model definition and the experiments and seek the problem elsewhere in the experimental design. They may reconsider the perspective so they can judge whether the scripts that they previously considered valid should be replaced by the scripts that are produced by the experiments. This is part of the traditional learning loop.

Case: Overlapping scripts

The two kinds of scripts overlap. In this case, the modeling teams have confidence in the model definition and the experiments as well as in the scripts. This raises a new question: do the would-be scenarios that were produced help the teams to switch from intuition to reality and back? If the answer is no, this means that the scenarios are either too intuitive or too close



Step 6 is concentrated on the evaluation of building blocks that were initially selected in step 1. This evaluation is based on a comparison of two sets of scripts: (set 1) the perspectives from step 2 with a priori expectations about simulated experiments, and (set 2) the scenarios from step 5 with a posteriori transcribed results of the experiments. Depending on the conclusions of the evaluation, a modeling team may decide either to go back to steps 3 and 4 and improve its models and experiments, or go back one step further and reformulate what scripts are valid. Both cases are part of the "Traditional Learning Loop". The team may also go "forward" to step 1 and improve its initial choice of building blocks. This move is concentrated on the meta-level and is part of the "Extended Learning Loop".

Figure 5.8 Step 6: Evaluate building blocks

to reality. In both cases, they fail to help the teams making a step forward to imagine new realities. The teams then reconsider the building blocks that were selected in step 1. This is part of the extended learning loop.	

APPENDIX A PART 3, FRAMEWORK FOR SYNTHESIS

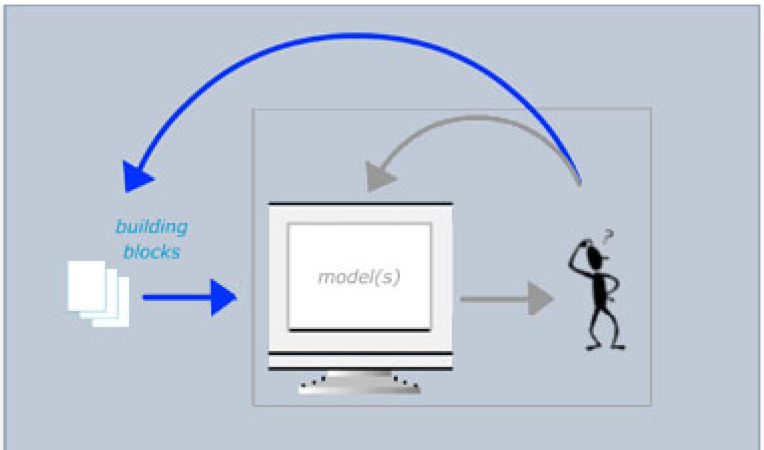
BUILDING BLOCKS

Abstract

An approach is proposed to develop and apply webs of interconnected building blocks that establish mappings of social theories. To build such webs, theories are reduced to syntheses of a small number of "building blocks", which themselves are abstract representations of theories, syntheses, models, concepts or ideas. Building blocks are not limited to social science. On the CD-ROM, a sample web is presented that includes concepts from the complexity sciences and biology. Once a web has been developed there are many conceivable ways of using it. In the Framework for Synthesis, building blocks help modeling teams to assemble "blueprints for synthesis", small coherent sets of building blocks, that lead up to diverging experimentation with agent-based simulation models. Further, the Building Blocks Card Game is proposed that allows groups of people, e.g. participants of a workshop, to interactively "navigate" a web of building blocks.

1. The Building Blocks Approach

Building blocks are vital ingredients for the Framework for Synthesis. They enable the extended learning loop (Figure 6.1) and guide modeling teams in the systematic exploration of hunches.



Building blocks enable the Extended Learning Loop. They provide a means to elaborate hunches - original ideas that drive simulated experiments with agent-based simulation models - first into blueprints for synthesis, then into models, and finally into experiments. This way, building blocks help to reflect on the Experimental Design and enforce the learning that occurs when experiments provoke new hunches.

Figure 6.1 The Extended Learning Loop with building blocks

The Building Blocks Approach

In a nutshell, the Building Blocks Approach is the development and application of webs of inter-connected building blocks. The webs can be compared with topological maps, drawn as network graphs, that establish mappings of social theories.

Building blocks themselves are abstract representations of theories, syntheses, models, concepts or ideas. Their abstractions serve one purpose: to highlight the interconnections among the building blocks. It is NOT a goal to describe isolated building blocks in detail.

Discovery

Through proper abstraction, interconnections can be discovered among social theories that only SEEM to be disconnected. In principle, theories are always approached as partly overlapping syntheses taken from the same web of building blocks.

Interdisciplinarity

Building blocks are not necessarily limited to social science. The sample map contained on the CD-ROM includes concepts from the complexity sciences and biology.

2. Creating a Web of Building Blocks

A sample web

The Building Blocks Approach is illustrated by a sample web that contains 37 building blocks

▸ The sample map can be explored using the Building Blocks Explorer on the CD-ROM.

The web was obtained considering groups of "postmodern" social theories (see Table 6.1), each group throwing different light on the interconnections among 4 themes:

- integration;
- complexity;
- communication;
- social networks.

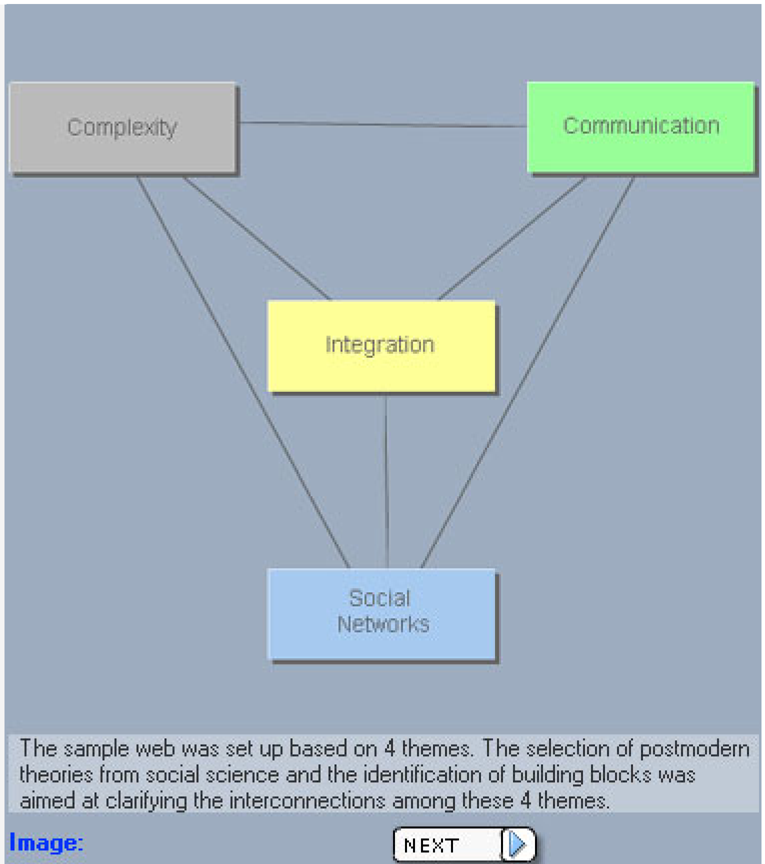


Figure 6.2 The sample web of building blocks

Themes and sub-themes

The 4 themes together with 14 sub-themes (see Table 6.2) helped to set up the web:

- Themes were picked at the start. They helped to conceive what groups of theories could provide the building blocks. To set up for an interesting web, themes were picked that have the attention of multiple disciplines.
- Sub-themes were identified when the web reached its final size. They helped to organize the web to be more efficient in documenting, visualizing, searching etc.

▸ The Building Blocks Explorer on the CD-ROM visualizes parts of the web concentrating on pairs of sub-themes.

Identification of building blocks

A standard approach for the identification of building blocks has not yet been developed. For the sample web, the following procedure was used:

- Attention was put on postmodern syntheses on different levels of aggregation in social science (societies, organizations, groups, individuals). See Table 6.1. Critiques on those syntheses were considered as well.

- On each level, it was straightforward to identify building blocks across themes. Building blocks were also picked from systems thinking as is practiced in the complexity sciences and biology.

Full details about the sample web are accessible through the Building Blocks Explorer on the CD-ROM.

Table 6.1 Selection of theories for the sample web

INTEGRATION	
System Dynamics	Forrester, Meadows, Sterman, Senge
Soft Systems Methodologies	Rosenhead, Checkland, Flood, Jackson
Consultancy	Klein, Vennix, Samuels
Organization Theory	Giddens, Stacey
Conflict Resolution	Suskind
Sustainability	Daly, Beck, Hawken, Hirschhorn
Industrial Ecology	Allenby
Ethics	Strijbos
Science	Kuhn
COMPLEXITY	
Biology, Artificial Life	Kauffman, Holland
Social Science	Axelrod, Eve, Horsfall, Gaustello
Science	Capra, Waldrop
COMMUNICATION	
Social Systems	Luhmann, Zolo
Organization Theory	Winograd, Dietz
Social Constructionism	Shotter
SOCIAL NETWORKS	
Policy / Management	ten Heuvelhof, Glasbergen, Nagurney
Science	Watts, Barabási

Table 6.2 The sample web's themes, sub-themes and building blocks

INTEGRATION	
Mind	Mental models, Thought & Feeling Structures
Ideas	Ethics, Paradigms, Metaphors, Scoping
Process	Consent vs. Dissent, Creativity and Innovation
Change	Agency for Change, Individual Change, Organizational Learning
COMPLEXITY	
Linearity vs. Non-linearity	Order, Equilibrium/Stability, Feedback, Selection, Evolution, Thermodynamics
Chaos	Strange Attractors, Bifurcations
Emergence & Self-organization	Dissipative Structures, Self-organization
Complex Adaptive Systems	Schemas, Adaptation
COMMUNICATION	
Social Systems	Meaning, Resonance, Codes & Programs, Paradox
Social Construction of Reality	Circle of Agency
Conversations	Transaction, Conversation, Communicative Act
SOCIAL NETWORKS	
Social Networks	Language Communities, Communities of Practice
Network Topology	Random Connectivity, Small World Property, Scale-free Property
Network Evolution	Preferential Attachment

3. Using a Web of Building Blocks

Possible applications of the Building Blocks Approach were explored in the two case studies of this thesis.

▸ The case studies documentation can be accessed through the CD-ROM's Resources section.

Building blocks and agent-based simulation

The Lisbon case study provided the opportunity to test the potential of the building-block approach against the dynamics of an actual agent-based simulation project.

- First, the sample web was used to critically reflect on the modeling team's focus and choices of concepts over time.
- Second, the potential contribution of building blocks to the modeling project was assessed, with special attention on whether or not increased learning potential would have been created.

Building blocks and rapid assessment

The Porto Alegre case study included an exercise that illustrates the use of building blocks in combination with the Rapid Assessment Program (RAP, see A.6). Since RAP was applied in this case study to support a LAN, this exercise also threw light on the potential use of building blocks to support LANs.

- First, new perspectives on the LAN's problem were generated, based on the RAP model that was built by the LAN participants over two workshops. Passing over three iterations, the original RAP-based perspective was enriched with additional building blocks.
- Second, it was reflected on when and how combinations of resources - building blocks, RAP, agent-based simulation models - could help a LAN to generate new perspectives on their problem.

Learning more about building blocks

More can be learned about building blocks in the following sections:

- This section's animation;
- the Building Blocks Explorer;
- the Building Blocks Card Game (see A.5).

▸ The animation presents a general idea of how a web of building blocks can be applied.

▸ The Building Blocks Explorer lets you zoom in on parts of the sample web and simply click on themes, sub-themes, building blocks and their interconnections to learn more about them.

▸ The Building Blocks Card Game allows groups of people to work with building blocks in an interactive workshop.

APPENDIX A PART 4, FRAMEWORK FOR SYNTHESIS

BASELINE SIMULATION MODELS

Abstract

A "Baseline" agent-based simulation model is proposed that allow modeling teams to quickly implement and run experiments about a wide range of social phenomena. The model is principally inspired by recent research on complex adaptive systems and large social networks. It is a simple generic model that focuses on how large heterogeneous populations of individual agents (people, organizations) are capable of adapting to outside pressures. Unlike agents in traditional economic models, the agents in this model do not rely much on rationality to adapt. Instead, adaptation involves mechanisms associated with emergence and self-organization. The model situates agents in a medium that is composed of multiple dimensions (geography, technology) and networks (social, cultural). It features innovative concepts that allow qualitative inputs and outputs for all dimensions and networks. The model's strength lies in its ability to convey concepts from the complexity sciences in a simple intuitive manner so that it can help convince managers and policy-makers about the importance of these concepts.

1. Introduction

Baseline Simulation Models are agent-based simulation models that help modeling teams quickly implement and run simulated experiments about social phenomena.

A sample Baseline Model

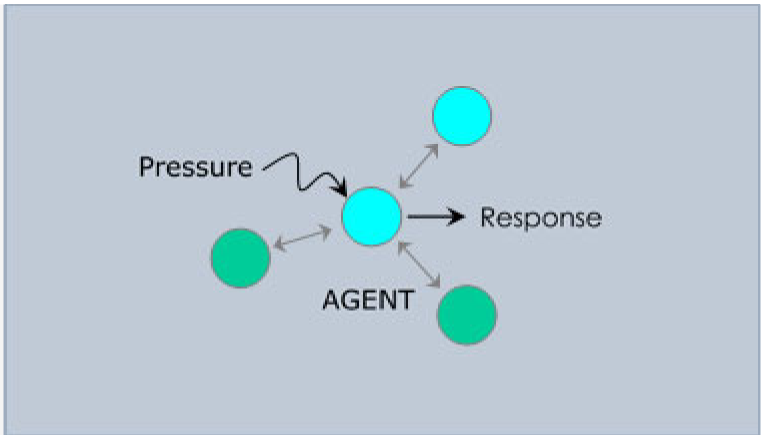
A sample Baseline Model was developed. This model is a simple, generic agent-based simulation model that currently runs in the Swarm[5] environment. It is principally inspired by well-known models from the mid-1990s (Axelrod 1997, Epstein and Axtell 1996 and in particular Holland 1995) that are connected to the groundbreaking work at the Santa Fe Institute in the mid-1980s (Waldrop 1992). The model is also inspired by ideas about biological evolution (Kauffman 1993) and networks (Watts 1999, Barabási 2002) that are currently being applied in the field of agent-based social simulation.

[5] Swarm is the first toolkit for agent-based simulation widely used in social science.

Adaptation

The sample model essentially shows how heterogeneous populations of social agents (people, organizations) are capable of adapting to outside pressures (see Figure 7.1).

Unlike agents in traditional economic models, the agents in the Baseline model do not rely much on rationality to adapt. Instead, adaptation involves mechanisms associated with emergence and self-organization[6].



An individual agent responds to outside pressure. The agent can respond because it can interact with other agents.

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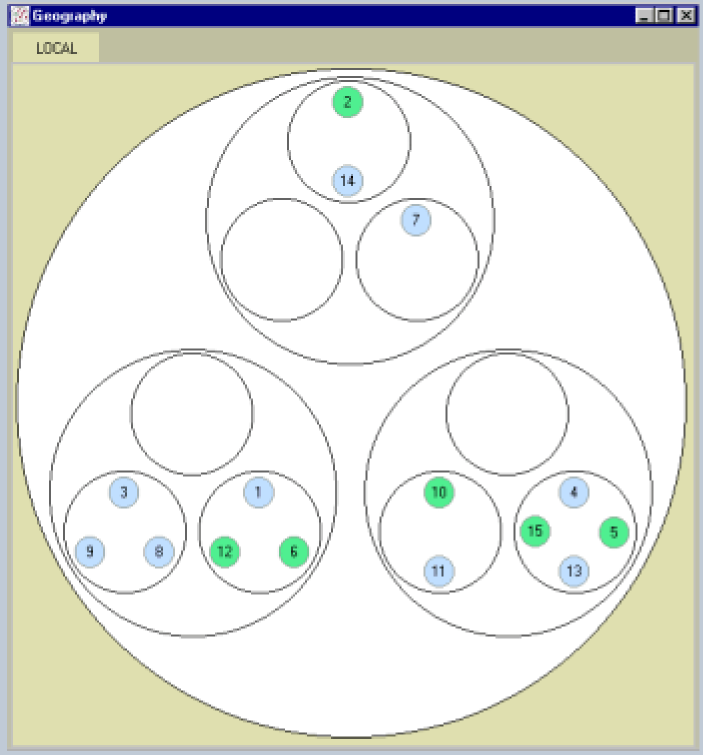
Figure 7.1 A simple model of adaptation to outside pressures

[6] These mechanisms were described by Holland (1995) and Kauffman (1993), among many others.

Dimensions and networks

To help uncover the "hidden" mechanisms for adaptation, the model situates agents in a medium that is composed of multiple dimensions (geography, technology) and networks[7] (social, cultural).

The individual actions of agents are based on local decisions that are influenced by constellations of agents in the dimensions and their linkages in networks. The consequences of their actions may collectively affect large-scale properties of these dimensions and networks on the longer run.



Representation of the geographical dimension. Agents that are geographically most proximate share the same smallest circle (e.g. agents 10 and 11). More distant agents may share the same larger circle (e.g. agents 10 and 13), which means that they are more proximate than agents that share only the largest circle (e.g. agents 10 and 7).

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Figure 7.2 Representations of dimensions and networks

Qualitative inputs and outputs

The model features concepts that allow qualitative inputs and outputs for all dimensions and networks. It also features visualizations and statistics[8] based on these concepts that assist in the interpretation of model behaviour.

▸ More about the model's main features on the page titled "Features of the Baseline Model".

Extensibility

Because the model is simple, generic and only uses qualitative data, it is flexible enough to support the extended learning loop. As part of this framework, the Baseline model can be extended along various directions.

▸ More about possible extensions on the page titled "Applications of the Sample Baseline Model".

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[7] The medium can also include abstract "supernetworks" (Nagurney 2002) representing linkages based on several types of relations between agents; e.g., linkages that indicate whether or not agents have compatible capabilities and also strong social ties. Supernetworks are useful for setting up workable (but not necessarily realistic) rules for decision-making by agents.

[8] The far-reaching implications of statistics on networks were demonstrated by Watts (1999) and Barabási (2002).

2. Rationale for the Baseline Model

Agent-based simulation challenges social scientists and modelers to rethink their traditional ways of doing things. The rationale behind the sample Baseline model corresponds to these challenges.

Challenges for social scientists

The novelty of agent-based simulation has often been articulated by pointing at the limitations of traditional models in social science, especially in economics. To put it simply, simulation gives agents "more space to breath" compared to the rational economic agents in traditional models.

But challenges for social scientists are greater than that[9]. McKelvey (1997) argued that social scientists should be concerned to understand the interplay of four sources of order (Table 7.1). Social scientists particularly tend to confuse order arising from complexity with rational order, or they ignore it. Yet it may be the interplay of the two sources of order where the phenomena of greatest interest are to be found (Goldspink 2000).

Table 7.1 Sources of order (McKelvey 1997)

Physical order	four forces of field theory
Organic order	natural selection
Rational order	decisions of rational actors
Complexity	emergence and self-organization

▸ The deliberations on sources of order are also done in the Building Blocks Card Game. See A.5.

Challenges for modelers

In agent-based simulation, modelers should be aware and develop understanding of the complexity paradigm and bottom up approaches to the simulation of complex systems and phenomena. This is learned by studying applications in biology, physics, mathematics, anthropology and many other disciplines.

What is problematic is that these applications demonstrate a shift in the way of thinking about models and modeling that tends to conflict[10] with previously learned frameworks and skills (corresponding to more traditional modeling practices).

One principal concern is that modelers are easily tempted to add more and more detail into their models, seeking advantage of the flexibility of the software programs that are used for running simulations. Yet the study of experiments with agent-based simulation models is often most rewarding at a deliberately chosen abstract level. Hence by adding detail a modeler introduces the risk of experiments becoming more accurate but less fruitful. This concern is articulated by Axelrod (1997) with the KISS-principle: Keep it Simple Stupid!

[9] Avoiding the limitations of more traditional approaches seems however to be an important part of the challenge. Goldspink (2000) discussed the potential value of a framework that helps social scientists avoiding concepts that "assume away many of the phenomena of interest". The proposed framework for experimental design (see Experimental Design) is a concrete step in that direction.

[10] Apparent differences should not lead modelers to the wrong conclusion that the "new" approaches are meant to replace the more traditional "old" approaches. It is important that modelers start to learn how to use top-down and bottom-up approaches in complementary ways. This requires from modelers that they put into perspective existing frameworks, tools and habits, develop new ones and amalgamate them in their modeling projects. See A.7.

Consequently, modelers should proceed carefully when making choices about maintaining certain abstractions in their models versus adding more detail.
One particularly critical choice concerns the type of agents used in a model. See Table 7.2. The KISS-principle implies that simple agents (and NOT sophisticated agents) might be the wiser choice[11].

▸ The tradeoffs associated with the choice of simple vs. sophisticated agents are also tackled in the Building Blocks Card Game. See A.5.

Table 7.2 Typology of agents (Goldspink 2000)

Passive agents / Objects	agents that have properties but do not initiate interaction
Active agents	agents having properties that allow them to interact with other agents
Reactive agents	simple active agents having a predefined and externally programmed scope of behaviour (rule set)
Adaptive agents	active agents that are capable of modifying some of their parameters or variable states or, in some instances, their rule set; they are possibly (goal) directed
Cognitive agents	agents that have an intrinsic capability to adapt and modify their own structure to accomodate recurrent perturbation
Biological agents	agents that embody fundamental characteristics of real biological entities (autonomous and self-producing)

[11] But to what extent can complex social phenomena be replicated using models with very simple or "minimal" agents? There seems to be no easy answer to this question. Take agent cognition for example. On the one hand, examples from biology remind social scientists that what resembles communication or knowledge representation (both requiring cognitive skills) may actually be consequences of structural coupling (cognition not required). On the other hand, the social theorists Castelfranchi and Conte have stressed that conclusions based on models with minimal agents can be misleading. These theorists argue that modelers introduce a bias when leaving out critical feedback relations in social systems that rely on cognitive skills of agents.

3. Features of the Sample Baseline Model

The Baseline model features concepts that help social scientist and modelers meet the aforementioned challenges (on the previous page). The concepts are:

- kenes;
- relative spaces;
- events.

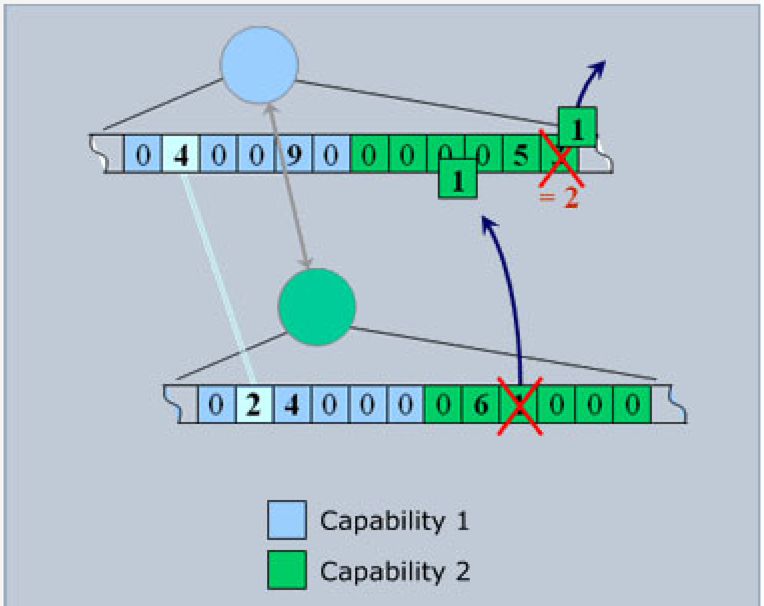
These concepts are powerful enough to examine the interplay of three sources of order:

- organic order;
- rational order;
- complexity.

Kenes & organic order

"Kenes" is a concept[12] borrowed from genetics that helps to perceive mechanisms for adaptation as in biological evolution; the likes of mutation and crossover, see Figure 7.3.

The Baseline model employs the concept of kenes to simulate how agents develop as they move around, learn new capabilities, etc. All agents in a simulation can be endowed with kenes. They are similar to genetic strings containing coded information that point to coordinates of agents in multiple dimensions.



Like their biological equivalents, kenes may undergo changes as consequences of interactions between agents (e.g. transfer of capabilities, see image). The Baseline model supports basic operations with kenes like mutation and crossover.

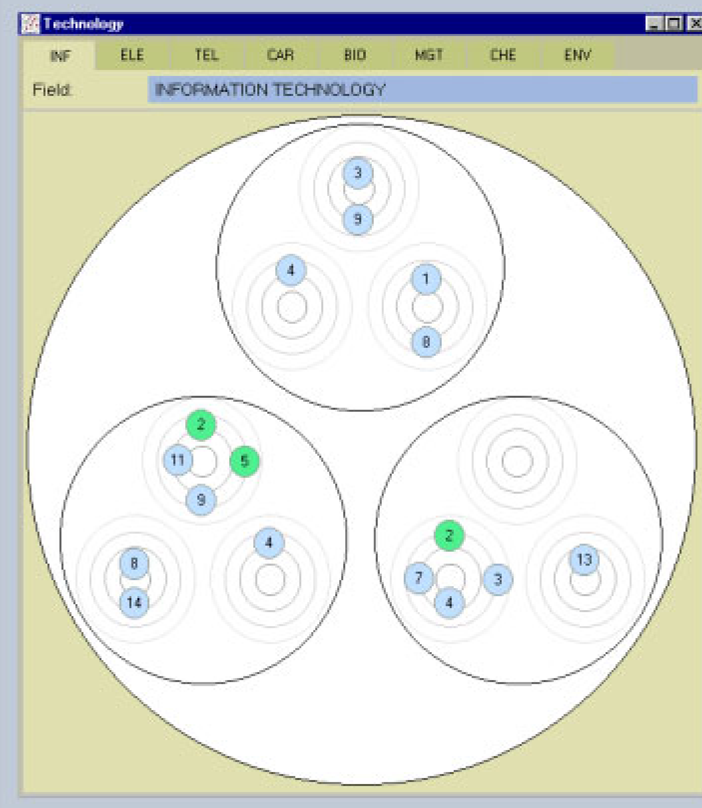
Image: NEXT

Figure 7.3 Uses of kenes

[12] Gilbert first proposed kenes, or "knowledge genes", to represent skills and technologies accumulated by firms (in Gilbert et al. 2001).

Relative spaces & rational order

Agents in the Baseline model do not rely on rationality to adapt to outside pressure. They do however make decisions, for example about with which other agents they will interact. To this end, agents are programmed to use simple hierarchies[13] to approximate constellations of agents in dimensions and their linkages in networks (see Figure 7.4).



To achieve decisions (e.g. with whom to interact?) agents have to somehow "profile" the many attributes of other agents (their coordinates in dimensions, their linkages in networks). A simple way for agents to achieve profiles is to rely on very simple hierarchies to classify other agents. These hierarchies are based on functions that approximate the proximity (or distance) between agents in the several dimensions and networks. These functions work with relative spaces, i.e. values for distances relate to other distances but not to a particular scale (e.g. "close" means "little distance compared to other distances"). Indeed the Baseline model does not require values for the attributes of agents in absolute spaces.

Figure 7.4 Use of relative spaces

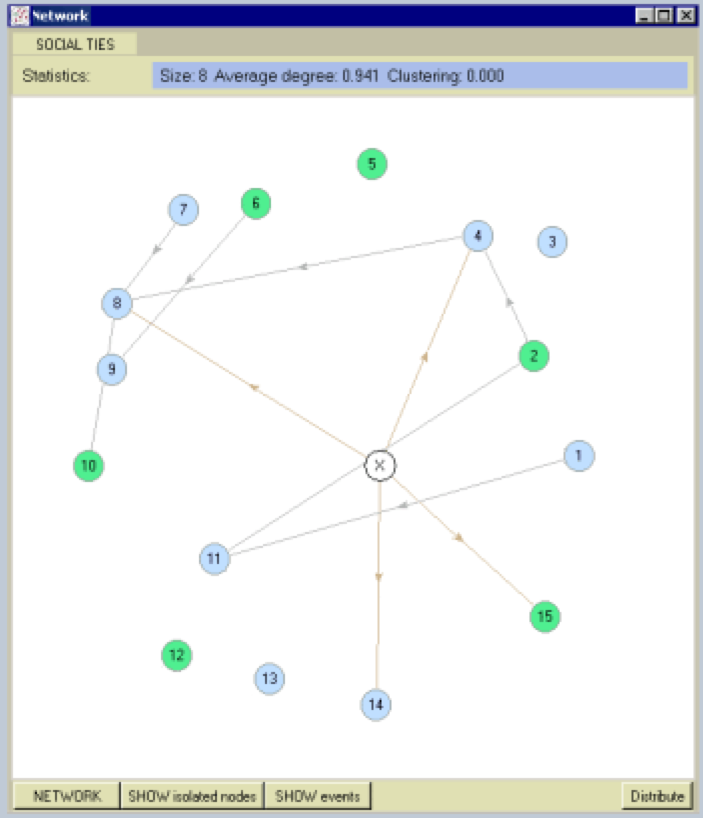
[13] Watts (2002) proposed a similar function for searching in social networks.

Events & complexity

The concept of "events" helps to model social network evolutions and integrate them with other types of dynamics (see Figure 7.5).

Agents in the Baseline model are to some degree "social" agents, meaning that agents also interact for motives other than responding to outside pressures. Their social and cultural interactions are considered to be embedded in the several dimensions (geography, technology).

Events can be used to explore the overall consequences of different types of connectivity in networks[14]. It is assumed that the type of connectivity that governs those networks may be the key to hidden mechanisms that underlie emergence and self-organization.



The concept of events simplifies the task of simulating social and cultural interaction. With this concept we no longer depart from the individual decision-making of agents, but generate realistic evolutions of linkages "run-time". Events in the Baseline model are essentially just another type of agents that do nothing more than establishing new linkages between agents. These agents can be associated with encounters, meetings, etc., or with the places where these social events take place.

Figure 7.5 Use of events

Simplicity

The abovementioned concepts - kenes, relative spaces and events - also help to keep models simple[15].

[14] Well-known types of connectivity in networks are "random", "small world" (Watts 1999) and "scale-free" (Barabási 2002).

[15] Simplicity is also achieved through the definition of social ties: "the total of all social linkages that influence the interplay between agents and other parts of their medium". This way it is not immediately necessary to include details about the different types of social linkages.

4. Applications of the Baseline Model

How can linkages between individual, autonomous agents sustain interaction and create value?

This question is central in problems like:

- How to strategize management of knowledge and innovation? (knowledge networks, innovation networks)
- How to cluster economic entities? (in industrial ecology, science and technology parks)
- How to promote value-creating linkages on a local scale? (linking infrastructures, commerce, habitats, etc.)

In each case, more puzzling questions need to be answered:

- How can the total be more than the sum of the parts?
- What kind of decision-making occurs on the level of agents? On the level of management or government?
- What are promising measures to stimulate the interaction between agents?

These questions is very hard to answer with traditional economic models:

- How can the contribution of particular set of linkages to overall performance be measured?
- Can assumptions about (rational) decision-making be justifiably made for all conceivable scenarios?
- Can one type of linkages (e.g. economic) be promoted without corrupting other types of linkages (e.g. environmental, social)?

More and more it seems that ideas about complexity and networks will provide the intellectual groundwork that help agencies find new answers.

Applications of the Baseline model

The Baseline model was applied in the Lisbon case study to generate would-be scenarios for a science and technology park. More specifically, the aim of the modeling was to identify and apprehend hidden mechanisms that trigger the emergence of a climate for innovation.

It turned out that measures that provoke the interaction between firms in the park constitute potential "lever points" for the park management that deserve further attention. The hidden mechanisms in this case were exemplified by the types of connectivity that govern the evolution of social and cultural linkages of in-park firms.

This result can be generalized to other cases, exemplifying that how well agents interact may depend to large degree on how their linkages evolve. In such projects, the Baseline model can help convincing managers and policy-makers that this view needs backup by scientific tools.

Taking agent-based simulation out of the laboraties

Nowadays agent-based simulation is still mostly done in laboratories, where social scientists collaborate with computer scientists to work on complexity and network-based ideas.

▸ Information about such laboratories can be found on the Internet. The web sites are listed under Resources on the CD-ROM.

Because the Baseline model is flexible and simple, it can help to take viable ideas out of these laboratories - even if they are not backed up by solid theory yet - and put them to test in the context of real case studies. More in particular, in conjunction with building blocks, the Baseline model can enable modeling teams to systematically explore these and related ideas; i.e., the systematic exploration of hunches.

APPENDIX A PART 5, FRAMEWORK FOR SYNTHESIS

THE BUILDING BLOCKS CARD GAME

Abstract

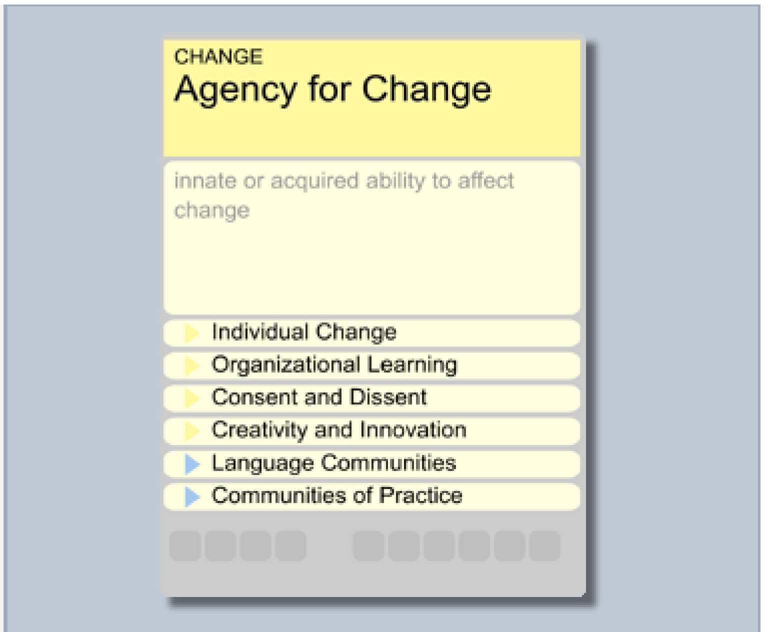
A "Building Blocks Card Game" is proposed that allows players (e.g. from modeling teams and/or learning-action networks) to work with building blocks in an interactive workshop. Each building block is represented by a card that contains a definition or short description of a concept or theory and its links to other building blocks (i.e. other cards). The links on the cards allow players to navigate a web of building blocks; i.e. to explore interconnections among building blocks that are little understood - or simply overlooked. Information on the cards enable a creative and systematic way of exploring those "hidden" interconnections. The game results in one or more blueprint for synthesis: coherent final sets of cards representing small webs of inter-connected building blocks. Further, an interactive workshop is proposed in which small groups of people can play the Building Blocks Card Game. This workshop provides a valuable opportunity for direct interaction between modeling teams and learning-action networks.

1. Introduction

A card game is proposed that allows modeling teams to work with building blocks in an interactive workshop.

The cards

Each building block is represented by a card containing a definition or short description of the concept or theory, as well as its links to other building blocks (i.e. other cards) (see Figure 8.1).



This card represents the building block Agency for Change, which corresponds to the theme Integration (indicated by its yellow color) and the sub-theme Change (indicated at the top of the card). The most important information is this card's six links with other building blocks (i.e. other cards).

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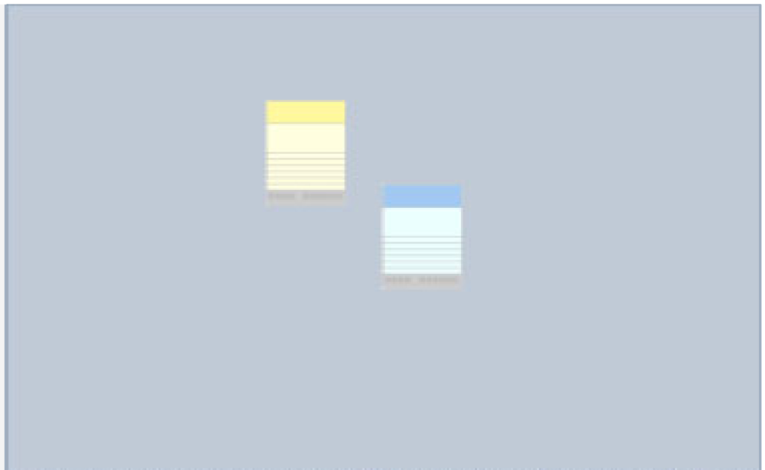
Figure 8.1 Examples of cards

Navigating a web of building blocks

The links displayed on each card allow players to navigate a web of building blocks (see Figure 8.2).

Blueprints for synthesis

The result of playing the card game is one or more coherent final sets of cards representing small webs of interconnected building blocks, or "blueprint for synthesis". The blueprints can be made part of a process of designing and studying simulated experiments with agent-based simulation models.



The process of navigating a web of building blocks can be portrayed as three steps that can be repeated an arbitrary number of times. The first step is to pick a small number of cards (for example, those that appeal most at first sight).

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Figure 8.2 Navigating a web of building blocks

Interactive workshop

An interactive workshop is proposed in which several small groups of people play the card game simultaneously. Groups are introduced to a social phenomenon of interest and are challenged with the game objective. Each group uses a deck of cards and creativity to achieve a blueprint for synthesis together with a proposal for simulated experiments. The game concludes with a short plenary in which groups present their proposals[16].

The workshop provides a valuable opportunity for direct interaction between modeling teams and members of learning-action networks. Groups should have at least one person from both "categories".

[16] The card game provides simple criteria for comparing and evaluating these proposals.

2. Game description

Game objective

Players are introduced to a social phenomenon of interest. The objective of the game is to conceive and think through simulated experiments that can potentially throw new light on that phenomenon[17].

Challenges for players

The immediate goal for players is to use the deck of cards to achieve a blueprint for synthesis together with a proposal for simulated experiments.

Major challenges for players correspond to two difficulties that social scientists and modelers experience when designing experiments with agent-based simulation models:

- for social scientists: which sources of order should they be concerned with?
- for modelers: for the implementation of an agent-based simulation model, how sophisticated should the agents be?

These are the same difficulties that are the rationale for the Baseline Simulation Models.

Social scientists: which sources of order?

Social scientists tend to assume that regularities particular to a social phenomenon are rooted in decisions that are rationally made. Likewise, players may tend to select building blocks that are familiar in this sense. This bias may however exclude the most interesting experiments with agent-based simulation models.

Simulated experiments can demonstrate that regularities are the result of the interplay of several sources of order (physical order, organic order, rational order and complexity). To prevent bias, players are challenged to "diversify" their proposals, assuming roles not only for rational order but other sources of order as well.

To guide players, cards may indicate the "mix" of sources of order that can be associated with the building block (see Figure 8.3).

Cards may indicate which sources of order can be associated with the theory or concept (at the bottom-left of a card). The "mix" of sources of order is indicative for the kind of light that the building block will throw on the phenomenon of interest. Each card also indicates which minimal agent type will be necessary when an agent-based simulation model is implemented (at the bottom-right). The minimal agent type is indicative for whether a simple model can be achieved or not.

Figure 8.3 Card indicates challenges for players

Modelers: which types of agents?

[17] The idea behind the card game is that in a later stage some of these conceived experiments will be implemented as actual models. For this reason, players should be somewhat familiar with agent-based simulation. A short demo about experiments with a simple model like the Baseline model can provide a good introduction.

Modelers tend to add too much detail into their models. Correspondingly, players should be careful when increasing the number of selected building blocks. Also, some building blocks require more details to be added than other.

Players are challenged to achieve blueprints that combine a small number of building blocks and propose experiments that can be implemented with simple models like the Baseline model.

To guide players, cards may indicate the minimal agent type that will be necessary when an agent-based simulation model is implemented (see Figure 8.3).

Game rationale

The rationale behind the card game is the same as the rationale behind the Extended Learning Loop: to use optimally the skills and experiences of players to assemble expressive blueprints for synthesis, and lay the basis for designing fruitful experiments with agent-based simulation models.

3. Game Play

Assignment

The problem is introduced and groups are formed (5 people per group is maximum).

Start of the game

Each group gets a deck of cards and two forms: the Blueprint form and the Proposal form.

Time schedule

This time schedule is based on a total playing time of approximately 1 hour.

1. Preparation	5 min.	Make sure you understand the assignment.
2. Brainstorm	5 min.	Check your group: does anybody already have hunches about interesting experiments? If so, write them down in a few sentences (use Proposal form)
3. Blueprint	25 min.	Start with one or more cards (base your initial selection on your group´s hunches) Repeat: ▪ Which cards are linked with this card? ▪ What are the interconnections? ▪ Select additional cards. Do your cards already "blueprint" the simulated experiments that will provide answers to the companies? Make a final selection of cards (use the Blueprint form)
4. Proposals	15 min.	Write down a short description of the simulated experiments (use Proposal form) Say something about: ▪ What are the key theories and concepts? (left column on Blueprint form) ▪ Which sources of order are of concern? (middle column on Blueprint form) ▪ Which agent types need to be implemented? (right column on Blueprint form)
5. Presentation	5 min. p/ group	Present your proposal
6. Evaluation	10 min.	

Evaluation of the proposals

Proposals are evaluated based on two questions:

- Can the experiments throw new light on the problem? (The Blueprint form provides an indication of the "diversification" of sources of order in experiments).
- Can the experiment be implemented with a simple model? (The Blueprint form provides an indication of the the "minimal" agent type in experiments.)

APPENDIX A PART 6, FRAMEWORK FOR SYNTHESIS

RAPID ASSESSMENT

Abstract

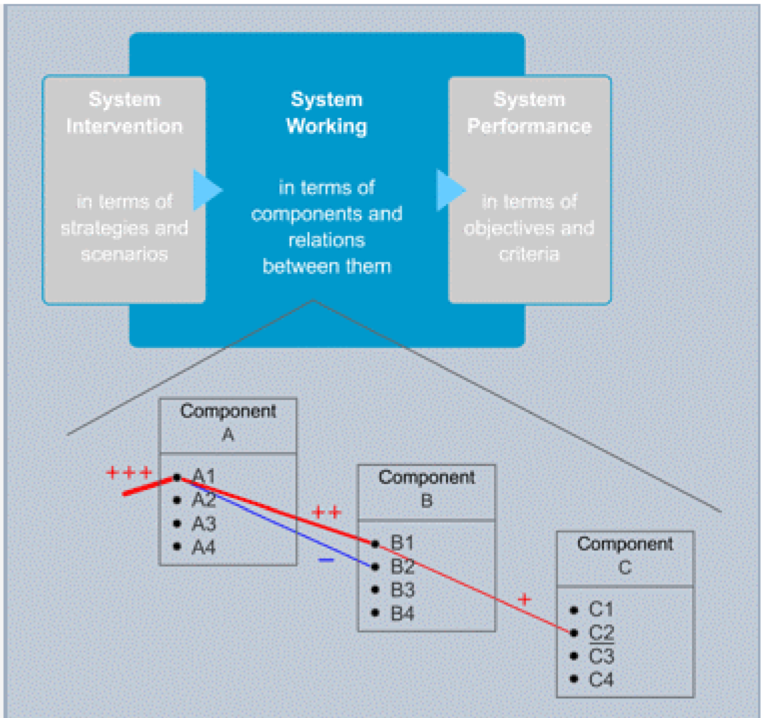
An interactive workshop is proposed that is based on the use the "Rapid Assessment Program" (RAP). With RAP, knowledge about a problem can be quickly integrated to qualitatively evaluate the consequences of policies - and especially the effects of interaction of those policies. The RAP software guides users through several steps in which the problem and goals are defined, a system representation is created, and effects of measures and exogenous effects are evaluated. New steps were designed by this thesis author that help integrate the participants' knowledge about actors into the RAP model. The extended model is called the RAP+ model. With RAP+, participants can easily adopt an "actor perspective" on their problem. A RAP+ session also promises to be a useful tool to facilitate the interaction between an agent-based modeling team and a learning-action network. It can throw light on scenarios that are centered on the dynamic interplay of actors, which are the most interesting scenarios to study with agent-based simulation.

1. Introduction

The Rapid Assessment Program (RAP)

With RAP knowledge about a problem can be quickly integrated to qualitatively evaluate the consequences of policies - and especially the effects of interaction of those policies. The RAP software guides users through several steps in which the problem and goals are defined, a system representation is created and effects of measures and exogenous effects are evaluated.

▸ The CD-ROM provides a link to a demo that explains in detail what RAP is, why it is developed, and how it can be used.



The essential activity in systems modeling with RAP is to represent a system's working in terms of components and relations between them. The relations are specified in qualititative terms. For example, the depicted fragment of a RAP model shows that a strong positive change in characteristic A1 of component A causes a moderate positive change in characteristic B1 of component B (component C is affected as well). Because the human mind is not good at propagating changes in large systems, the RAP software helps to analyze a RAP model, put ends (objectives) vis-à-vis means (strategies) and discover surprising policy interactions.

Figure 9.1 Systems modeling with RAP

RAP Workshops

A methodology is developed for RAP that employs interactive workshops to guide participants from their policy problem to potential solutions. The interaction in these workshops helps ensure that users of RAP models have faith in the results. Typically these workshops seek the participation of experts and non-experts.

RAP workshop may support projects with insights about:

- What are the promising policies?
- What are the areas of research that deserve more attention?
- What knowledge do non-experts have about the problem?
- What are useful indicators to measure performance of policy-makers?

RAP+

Although the RAP software does not preclude incorporation of knowledge about actors and their relations, it offers no explicit way of doing so. As a result, consequences of policies are evaluated without taking into account that the most interesting scenarios may be those that are generated by the dynamic interplay of actors.

New steps are proposed to extend the RAP methodology, designed to enable participants to incorporate explicitly knowledge about actors into the system representation. These steps guide participants in shifting from an objective to an intersubjective viewpoint on their policy problem and potential solutions. Their knowledge about actors is represented in a way that makes it possible to use this knowledge in the evaluation of policies.

▶ The new steps and a RAP+ model are described in the Porto Alegre case study.

Complementary uses of RAP+ and agent-based simulation

RAP+ workshops can function as a backbone for the design and study of experiments with agent-based simulation models. An exercise, based on the results from the workshops in the Porto Alegre case study, helped to learn more about how complementary the two approaches are[4].

▶ The exercise is presented in the Porto Alegre case study.

2. The RAP/RAP+ Workshops

It is straightforward to plan RAP/RAP+ sessions as a series of two self-contained workshops.

Workshop 1

The goal of the first workshop is to integrate knowledge of participants about their problem[4]. The RAP software helps to guide the participants through the six steps listed in Table 9.1.

▸ The RAP demo explains each step in detail.

The result of this workshop is a systems model - the RAP model - that can be used to qualitatively evaluate the consequences of policies.

Table 9.1 Design of workshop 1

✓	Step 1.	Describe the problem
✓	Step 2	Define the objectives
✓	Step 3	Define the elements in the system under investigation
✓	Step 4.	Define the interactions between these elements
✓	Step 5.	Analyze and evaluate the changes as a result of strategies
✓	Step 6.	Compare the various options

Workshop 2

The goal of the second workshop is to integrate knowledge about the actors into the RAP model[5]. To this end, steps 3 to 6 are iterated one more time (Table 9.2). The knowledge of participants about actors is also represented qualitatively.

▸ The Porto Alegre case study (see Resources) illustrates how this new knowledge is integrated into the RAP model to achieve a more complete assessment of the problem.

Table 9.2 Design of workshop 2

✓	Step 1.	Describe the problem
✓	Step 2.	Define the objectives
✓✓	Step 3.	Define the ACTORS in the system under investigation
✓✓	Step 4.	Define the interactions between these ACTORS and the system
✓✓	Step 5.	Analyze and evaluate the changes as a result of strategies
✓✓	Step 6.	Compare the various options

3. Applications of RAP

The Rapid Assessment Program has been applied to support a number of projects in sustainable development.

▸ See this chapter's animation (the RAP demo) for a list of projects.

RAP and learning-action networks

The first intentions of the developers of the RAP software were to design a tool that could assist in modeling projects. Basically, the tool was applied to help modelers quickly integrate expert knowledge. Interestingly, the initial concept of the tool has been replaced by a more modern concept: facilitating the interaction and communication between policy-makers, scientific experts and non-experts.

This shift is making RAP a more suitable tool to help support learning-action networks, since one of the distinctive characteristics of LANs is that participants actively seek to cross boundaries between them (institutional, organizational, disciplinary, language).

APPENDIX A PART 7, FRAMEWORK FOR SYNTHESIS

THE FRAMEWORK FOR SYNTHESIS

Abstract

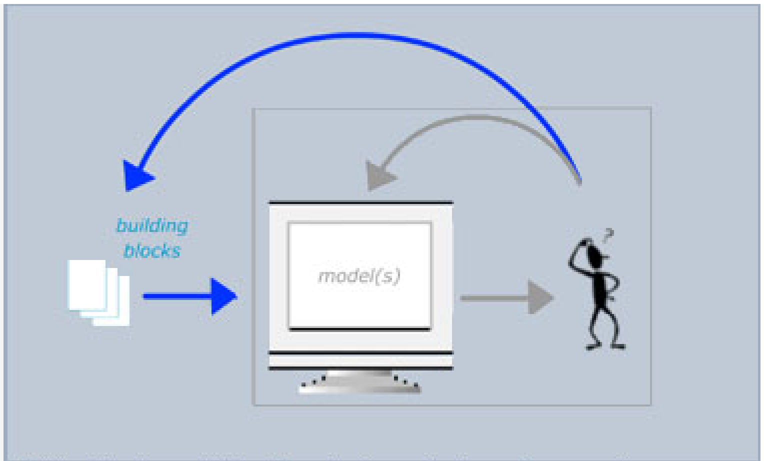
The Framework for Synthesis outlines how its tools and methods can be applied in conjunction to support learning-action networks. To add flexibility, the Framework does not seek an immediate integration of its tools and methods; instead it organizes the possibilities for their interactions according to a proposed five-layered architecture. The architecture has two foundation layers, one middle layer and two top layers. The foundation layers, an agent-based simulation support layer and a learning-action network support layer, can be seen as a way to achieve applications with agent-based simulation in a more problem-oriented, integrative and interactive fashion. The middle layer is dedicated to the facilitation of a unifying process to building would-be worlds. This is the level at which a high-level modeling language can help glue together the elements on the lower layers. The fourth and fifth layers provide user-friendly ways of interaction with the lower layers. These layers are the individual tools and methods of the Framework for Synthesis and the integrated INTERSECTIONS workbench respectively.

1. Introduction

The Framework for Synthesis essentially outlines how the tools detailed in A.2 through A.6 can be combined to support learning-action networks.

▸ See A.1 for a discussion of the specific challenges for support of learning-action networks.

▸ A description of the "ideal" Framework for Synthesis was included as part of the roadmap leading to this CD-ROM (in Chapters 2 through 4 of the author's Ph.D thesis).



Building blocks enable the Extended Learning Loop. They provide a means to elaborate hunches - original ideas that drive simulated experiments with agent-based simulation models - first into blueprints for synthesis, then into models, and finally into experiments. This way, building blocks help to reflect on the Experimental Design and enforce the learning that occurs when experiments provoke new hunches.

Figure 6.1 The Extended Learning Loop with building blocks

Flexibility

As is shown on various occasions in the previous chapters, it is possible to use the tools in conjunction as if they were all part of one integrated workbench. For this reason, the Framework for Synthesis is considered to lay the groundwork for the INTERSECTIONS workbench.

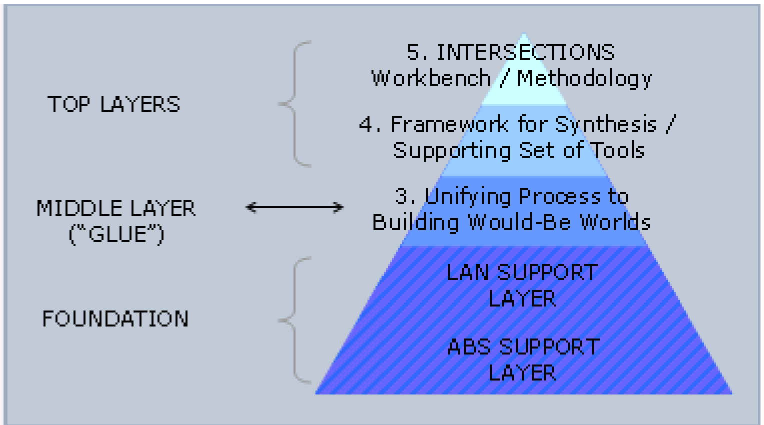
The Framework can only be sufficiently flexible if its ingredients can be made to interact in different ways depending on the application. Therefore, even though the six steps of the Experimental Design - a framework within the Framework for Synthesis - outline how tools can interact well, more is needed to determine what integration of tools would suit best a particular situation at hand.

2. The Framework's Architecture

The Framework for Synthesis' architecture helps to structure how its tools can be combined into practical applications.

Multi-layered architecture

Because a high amount of flexibility is desired (in line with the comments on the previous page), a five-layered is proposed (see Figure 10.2).



The Framework's five-layered architecture can be viewed as two foundation layers and two top layers glued together by a middle layer. A high-level language could do the job of glueing elements of the two foundation layers together depending on what happens in the two top-layers.

Figure 10.2 The Framework's five-layered architecture

Foundation layers

The Framework's architecture has two foundation layers:
- 1st layer: the agent-based simulation (ABS) support layer;
- 2nd layer: the learning-action network (LAN) support layer.

The ABS Support Layer is concentrated on how webs of building blocks and agent-based simulation in conjunction can best facilitate the Extended Learning Loop.

The LAN Support Layer is concentrated on the creation of perspectives and would-be scenarios, which can be evolved using various resources in conjunction: building blocks, simulated experiments with agent-based models and rapid assement models.

Together, the foundation layers can be seen as a way to achieve applications with agent-based simulation in a more problem-oriented, integrative and interactive fashion.

▸ The interaction of the layers is exemplified with the Building Blocks Card Game. See A.5.

Middle layer

On top of the foundation operates a middle layer:
- 3rd layer: the middle layer

The middle layer is dedicated to the facilitation of a unifying process to building would-be worlds. This is the level at which a high-level modeling language can help glue together the elements on the lower layers.

Top layers

Interaction with users occurs through the two top layers:
- 4th layer: the Framework for Synthesis and the supporting tools and methods;
- 5th layer: the INTERSECTIONS workbench / methodology.

The fourth layer allows customization of the Framework for distinct applications, offering the Framework's basic tools that can work in conjunction in different ways.

The fifth layer is the integration of these tools into a full-fledged workbench to help achieve adaptiveness in strategic planning: INTERSECTIONS.

3. Applications of the Framework

The Framework for Synthesis and its tools were designed to support learning-action networks, and especially to help their members achieve adaptiveness in strategic planning.

Foresight institutions

The main category of potential users of the Framework for Synthesis is foresight institutions. They are national or global think tanks sponsored by international organizations, government departments, or corporations. Their principal activity is scanning future opportunities and needs with focus on particular fields of strategic interest (emerging scientific fields or technologies, changes and risks for societal groups or society at large, etc.). Besides providing strategic policy advice to their sponsors, they usually run programs for research and training. In their work they combine skills like trend analysis, scanning of emerging issues and scenario construction. They put a strong emphasis on networking and organize their projects through connecting nodes (groups of individuals and institutions) that are geographically dispersed (e.g. foresight institutions are often connected with other think tanks).

Foresight and learning-action networks

Learning-action networks are likely to have a critical role in foresight. This is illustrated in the Porto Alegre case study (see Resources) in which universities act as institutions of foresight. In that case, foresight was created through an informal strategic planning workshops that was meant to consolidate and extend the (informal) network to include business planners, policy makers, governments, corporations and NGOs.

Contribution of the Framework for Synthesis

All foresight insitutions share a common underlying assumption: that the future is essentially unpredictable, and no "accurate" predictions should be sought, but rather ranges of plausible outcomes. Also, they all consider the process itself as providing the payoff for the activity since it tends to create a framework for discussion and induce flexible thinking.

Given this view on what is the essential contribution of foresight, it can be assumed that foresight institutions will benefit from the Framework's capacity to generate would-be scenarios in rapid, interactive and systematic ways, while covering unconventional perspectives that are rooted in complexity studies and agent-based simulation.

APPENDIX B PART 1, LISBON CASE STUDY

CHRONOLOGY OF THE MODEL DEVELOPMENT PROCESS

1. Introduction

The development of model covered four phases:
1) Start;
2) Prototype;
3) Meta-model;
4) Case Study.

The next pages chronicle each of the four phases. For each phase, the team's most relevant activities are listed, followed by a display of the most relevant ideas that were generated by the team members.

The research team:
- artificial intelligence, agent-based simulation (1 scientist);
- economics, agent-based simulation (2 scientists);
- economics, geography (2 scientists).

2. Chronology

Stage 1: Start

- One of the scientists in the team, with economics/geography background, had already been involved in a previous study of Taguspark. That study was designed to discover to what extent the environment provided by the S&T park had contributed to improving the innovation capacity of the in-park firms. The environmental factors that had been examined included the educational and professional backgrounds of entrepreneurs in Taguspark, the "social time" in Taguspark, and other factors that could explain the "park effect", or the lack of such.
- Initial contact with Taguspark had been established.
- At this early stage, the specific interests of team members included:
  - urbanism, particularly the microgeography of Taguspark;
  - evolutionary economics, particularly applications of "genetic algorithms";
  - the strand of mathematical research that was concentrated on the analysis of the topologic properties of networks, and in particular the research on "small worlds" and "scale-free models".

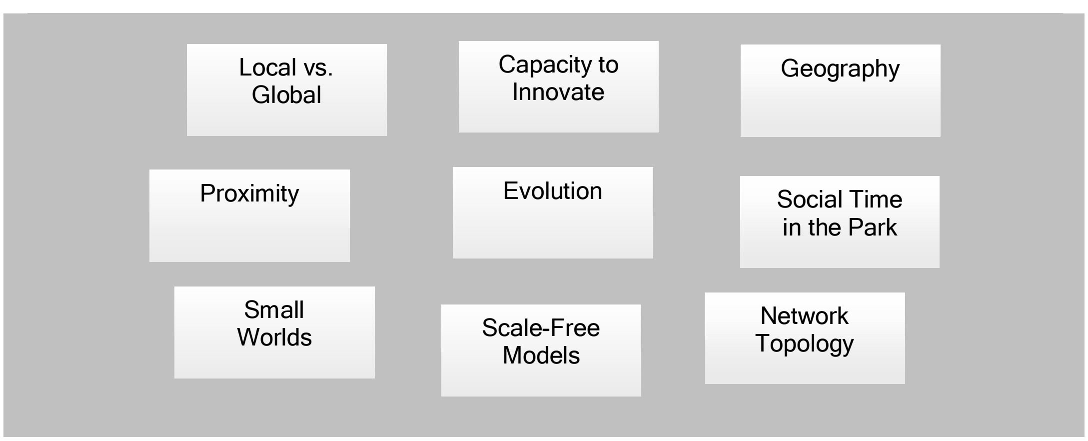


Figure 1 The main ideas of the research team at the start of the project

Stage 2: Prototype

- An important paper was published in the on-line "Journal of Artificial Societies and Social Simulation" (JASSS). This paper, with the title "Innovation Networks - A Simulation Approach", written by Nigel Gilbert, Andreas Pyka and Petra Ahrweiler, contained useful ideas like "innovation networks", "kenes" and "innovation oracle", that were highly relevant for the team's evolving work.
- The team developed a first prototype, containing ideas like "kenes" and "network events".
- An abstract for a paper was written for the International Association of Science Parks Conference. In this abstract, the team set out its plans to develop a tool for park managers with the name "INTERSECTIONS" and included a short presentation of the prototype.

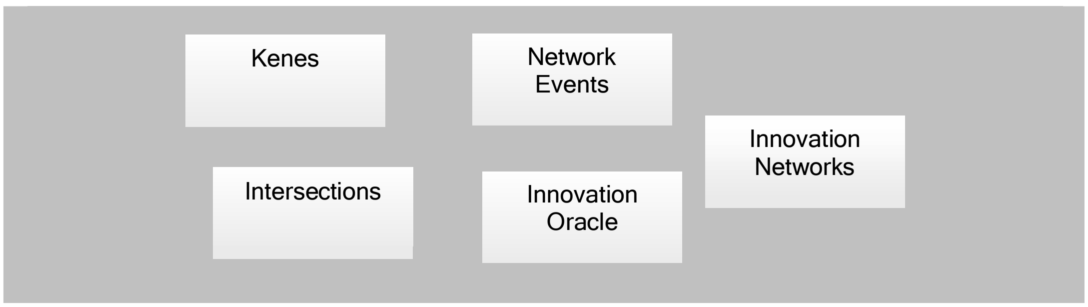


Figure 2 The team's main ideas when the prototype was being developed

Phase 3: Meta-model

- The team established its plans in a presentation for the Taguspark management and demonstrated the prototype. This meeting was crucial for the "go" of the case study.
- For the meeting, it was necessary to clarify the link between the model and the empirical data to be collected through interviews with entrepreneurs in the park. To this end, a meta-model was developed that integrated various ideas that the team wanted to explore further and that was presented in the Taguspark meeting. The meta-model was structured around four keywords: "variety", "proximity", "form" and "change". See Appendix B.3.
- Regarding network topology, the Taguspark management expressed interest in links with the outside of the park rather than inside, which left open the question of which geographical scale to use.

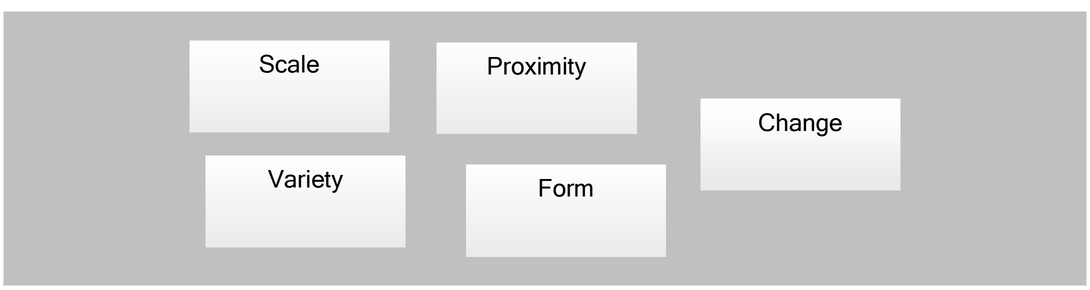


Figure 3 The team's main ideas when the meta-model was conceived

Phase 4: Case Study

- The team conducted a survey in Taguspark, using an extensive questionnaire to obtain data on 30 firms in the park through interviews with managers. The analysis of the data focused upon three specific interests:
  - Variety in Taguspark (extensive);
  - Topology of network inside Taguspark (complete);
  - Topology of network with the outside (limited to an example).
- Based on analysis of the survey data, three hunches were produced by the team:
  - Stimulating the interactions of park residents through articulation of the park's microgeography;
  - "Missing ingredients" in the Taguspark "mix";

- Microfirms becoming innovative.

These hunches are presented in Appendix B.3.

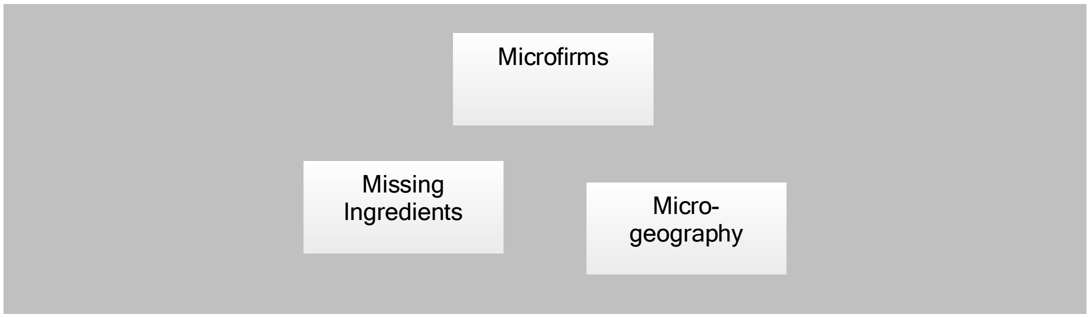


Figure 4 The team's main ideas after the analysis of the Taguspark survey data

3. Overview

The complete chronology of the model development process is presented in Figure 5. The chronology shows that the model development process featured an early "lock-in" on a set of ideas and primitives that were put forward at the start and then incorporated in the prototype.

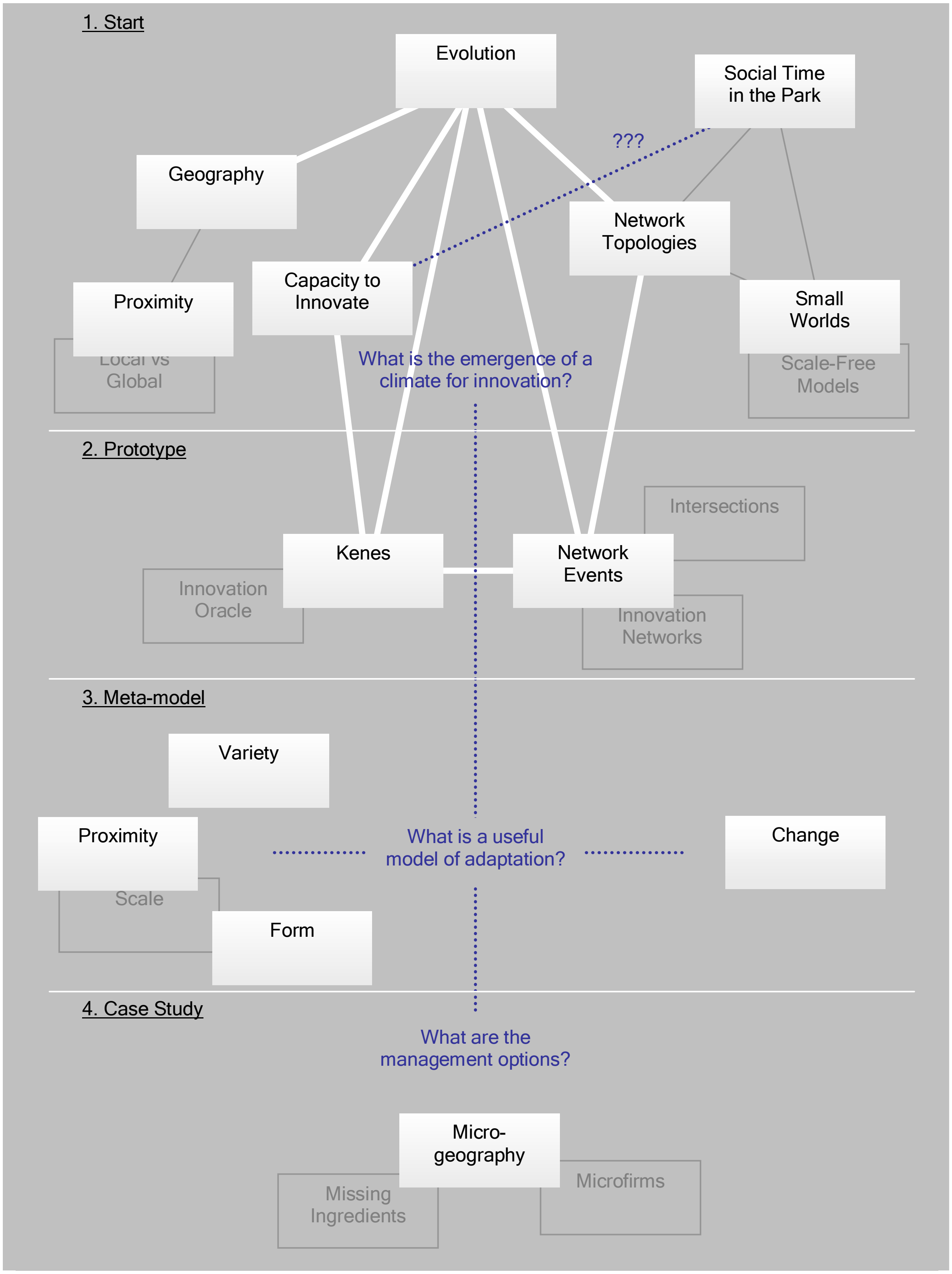


Figure 5 The team's early lock-in on a set of ideas

APPENDIX B PART 2, LISBON CASE STUDY

DESCRIPTION OF THE INTERSECTIONS MODEL

1. Focus of the Model

(Paragraphs appear as numbered items as they may reference each other.)

Innovation and social networks

1 Without doubt, social networks are important for innovation and are becoming more important because of today's trends (the "knowledge based society"). However, the complexity of innovation processes and social networks make their joined analyses using conventional economic models very difficult. INTERSECTIONS is an agent-based simulation model that can be used to explore questions about innovation and social networks and to find answers that are relevant to the management of innovation.

Innovation theory

2 The increasing importance of social networks for innovation has motivated recent contributions to innovation theory from economics and sociology. New innovation theory even suggests that in light of today's trends, innovation processes should be organized around networks; i.e. the concept of "innovation networks". Nigel Gilbert, Andreas Pyka and Petra Ahrweiler demonstrated the potential of embodying this new theory and the related concepts - while still being "under construction" - in an agent-based simulation model (Gilbert et al. 2001).

Evolutionary perspective

3 Given the dynamic nature of the innovation process and of the linkage in social networks, it makes sense to examine them from an evolutionary perspective. With innovation, we think of evolution in terms of "technological trajectories" of firms, that we observe in INTERSECTIONS using a visualization of "technological space". We think of evolution of social networks in terms of network growth, clustering, etc., that we observe in INTERSECTIONS using a "dynamic graph", a technique for visualization of networks changing over time, in combination with statistics.

Interactions of actors[18]

4 A main theme in innovation theory is the importance of interactions of firms, policy actors, universities, research laboratories, etc. In a "knowledge based society" no single actor has the capacity to accumulate all knowledge needed for innovation; i.e., the innovation process is an interactive process that involves learning as a result of the interaction. In INTERSECTIONS we adopted this perspective and placed interactions among actors central in both evolutions (innovation and social networks).

Goal-seeking and contingencies

5 The resultant evolutions tell stories of both goal-seeking and contingencies. Actors formulate hypotheses about successful innovations, but also stumble on new ideas through the interaction with others. They make efforts to improve their positions in the social network, but are aware that accidental encounters (for example people start a conversation while queuing in a restaurant) can also start important new chains of connections.

Self-organization

6 We chose to examine these stories of goal-seeking and contingencies not as separate interactions, but we looked for patterns of interactions. We did not expect to find a blueprint for these patterns; our focus was upon truly "bottom up" processes of change. This kind of change involves agents organizing themselves to produce a new pattern that cannot be reduced to the behaviour of the agents; something new happens and there is true synergy. We refer to this self-organization as the "emergence of an innovative climate".

7 If an innovative climate emerges, it is certainly not at equilibrium. Instead, it will require great effort to be maintained and relatively little effort to change it.

Agent-based simulation

With the agent-based simulation model INTERSECTIONS we:

[18] In INTERSECTIONS and throughout this document, all entities that are involved in the innovation process are referred to as "actors".

- ran simulations in which a large population of software "agents", representing actors like firms and institutions, interact with one another. The many interactions between agents constituted the dynamics of the (simulated) innovation process and the (simulated) linkages in social networks.
- observed the interactions (on the micro-level) as well as their consequences seen from an evolutionary perspective (macro-level). On the micro-level, we observed individual decision-making of agents (e.g. with whom to interact?). On the macro-level, we observed technological trajectories of all agents and the evolution of their social network.
- recreated instances of goal-seeking and contingencies. We defined a set of rules that determined how agents behaved when they interacted, and included an element of chance.
- Examined patterns; supported by multiple visualizations of simulation data, we looked for changes that point to self-organization and the emergence of an innovative climate.

Focus

8 The focus of the INTERSECTIONS model is summarized in Figure 6.

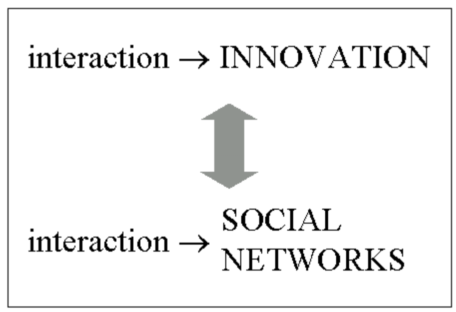


Figure 6 Focus of the INTERSECTIONS model

Application of the model in Taguspark

9 The INTERSECTIONS model was developed to support the management of innovation. In order to develop the model into a management tool that could be used in practical applications, our approach involved a case study of "Taguspark", a science and technology park near Lisbon.

Methodology

10 We employed a methodology that accommodated the particular role of modeling in an agent-based simulation. In short, we used the simulation model to function as "a halfway house between data and theory".

11 Our methodology also engaged people in a particular use of the model that differs from uses commonly associated with simulation (e.g. prediction). In short, the INTERSECTIONS model was used to generate "would-be scenarios" that allowed us to switch from intuition to reality and back again.

Roles for geography

12 For the Taguspark case study we extended our focus to include the role of geography. We distinguished local vs. global and explored their meaning in terms of the evolutionary processes related to innovation and social networks. In particular, we looked at the potential contribution of geography to the emergence of a (local) climate for innovation.

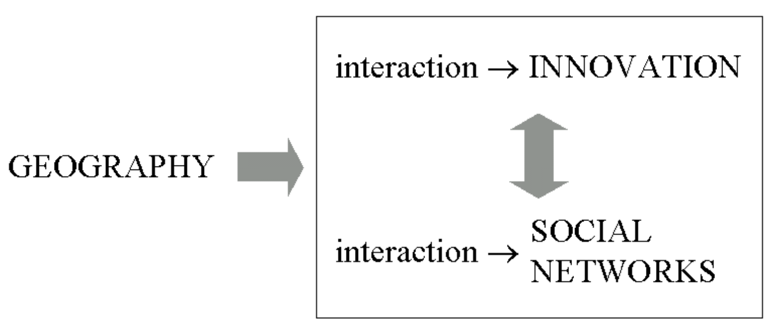


Figure 7 Focus of the application of INTERSECTIONS for Taguspark

2. Abstractions

Interactions → Innovation

What is innovation?

13 Innovation is the successful exploitation of new ideas. In INTERSECTIONS not all parts of the innovation process, from idea to successful exploitation, were given equal attention. Exclusive attention was given to how actors update their skills and technologies (the R&D component of innovation).

14 The skills and technologies that an actor has accumulated over time were represented by a genetic code called a "kene" (Gilbert et al. 2001). In a kene are stored in a "bar code" manner the levels of expertise that an actor has acquired in specific niches within different technological fields. The basic idea behind the use of kenes is:

- a kene stands for the technological trajectory that a particular actor is following;
- kenes are subject to "mutation" and "crossover" (see 15);
- together the kenes of all actors constitute a "variety pool" that largely determines the potential for innovation among the population.

15 In the context of the INTERSECTIONS model, innovation means the mutation or crossover of kenes:

- mutation occurs when an actor decides to "go-it-alone" and innovates following a pioneer strategy;
- crossover is the result of innovation strategies "imitate" or "collaborate" that involve interaction between actors.

16 Of special interest are those recombinations of kenes that result in the acquisition of skills or technologies that were not present in one of the kenes before. We called this radical innovation, in contrast with incremental innovation.

Why innovation?

17 INTERSECTIONS was not designed to provide an elaborate answer to the question: WHY innovation? An exogenous pressure to innovate was assumed, to which all actors were (equally) exposed.

18 We believed that this simplification could be justifiably made in cases like ours involving firms and institutions in Taguspark. Here, the general picture was one of actors operating in local markets with weak demand for innovation, but maintaining crucial links to actors that are active in global markets with strong demand for innovation. The pressure to innovate stems from the imperative not to stay behind together with the advantage to distinguish themselves as "innovative" on local markets.

19 Accordingly, in simulations with INTERSECTIONS it was permitted that, with certain frequency, opportunities arose for actors to make an effort to update their skills and technologies (each time step in our simulations we "activated" a small number of actors). An activated actor can follow one of three possible innovation strategies: go-it-alone ("pioneer") or interact with other actors ("imitate" or "collaborate"). The probability of an actor following a certain innovation strategy is known in advance, but whether the actor, in fact, does so is determined only when the program is run. (The software as it were rolls a pair of dice for each actor.)

Technological trajectories

20 There were no preconceived technological trajectories in INTERSECTIONS, nor did actors formulate hypotheses about successful innovations. Trajectories emerged as a result of mutations and crossovers of kenes with no reference other than the kenes themselves, i.e. the mutations and crossovers that happened in the past resulted in a variety pool that largely determined the possibilities for further mutations and recombinations.

Benefits of innovation

21 Direct feedback mechanisms like rewards attributed by markets to innovations or to innovation hypotheses are not included in INTERSECTIONS. Again, this conforms to situations like the team found in Taguspark and that are characterized by local markets with weak demand for innovation.

22 However, indirect feedback was provided by the social network (see 28 and 29).

Marketing

23 No attention was given to the successful exploitation of the R&D effort. It was simply assumed that if actors were able to meet the pressure to innovate they survived; if not, they disappeared.

Interactions → Social Networks

Social ties

24 Social networks can contain many kinds of links. In INTERSECTIONS, links were limited to social ties among actors. We thought of social ties as being anything from close friendships to recently made business contacts that were based on common properties like:

- compatibility of skills and technologies;
- common cultural or educational background;
- overlap in social networks.

Trust

25 In INTERSECTIONS, creation of social ties was based upon trust building. There was no explicit representation of trust among actors; we considered trust to be fully captured by the configuration of the social network. This is a view that is defendable in light of today's trends. An advantage of considering the social network and trust as being two sides of the same coin was that we could immediately recognize the relevance of social ties for the interactions among actors.

Encounters

26 New or strengthened social ties among actors could be established as a result of "encounters". (In 28 it is stated that social ties can also be a result from collaboration for innovation.) Encounters are instances when actors, or rather, people representing them, physically meet at a certain location.

Events

27 "Events" are settings for encounters to take place. In INTERSECTIONS settings for formal, staged encounters like conferences were considered as well as settings for informal, accidental encounters (e.g. people start a conversation while queuing in a restaurant). Movements of people were not explicitly modeled, but implied with events.

Innovation ↔ Social Networks

Innovation → social networks

28 Collaborative efforts to innovate resulted in new or strengthened social ties among the actors involved.

Social networks → innovation

29 Social ties among actors was based on trust (see 25) and increased opportunities for imitation or collaboration.

Self-organization

Patterns

30 As is stated in 6, we examined the evolutions related to innovation and social networks not as separate, but by looking for patterns of interactions. Our abstractions 13-29 yielded us a look at two kinds of patterns in particular: "coupling" and "clustering".

Coupling

31 Coupling among actors was a pattern of simultaneous convergence and divergence of technological trajectories. Through crossover with kenes, actors became increasingly similar to some and at the same time increasingly different from others.

Clustering

32 Clustering is a well-understood pattern in social networks. In short, clustering meant that if an actor is connected to two other actors, these two actors are likely to be connected to each other as well.

Self-organization

33 With INTERSECTIONS we examined the significance of coupling and clustering for self-organization and the emergence of a climate for innovation (see 6).

The Roles of Geography

Geography → innovation

34 Geographical proximity implied trust (e.g. a shared cultural background) and increased opportunities for innovation. The impact of geographical proximity was similar to that of social ties, see 2.17.

Geography → social networks

35 Actors that were geographically proximate were more likely to encounter each other. This made it more likely that these actors established social ties.

Local vs. global

36 To examine the role of geography more closely, we distinguished:

- the "local" variety pool, of the kenes of all local actors together, vs. the "global" variety pool;
- the "local" network, with all social ties among local actors, vs. the "global" network.

Local climate for innovation

37 With INTERSECTIONS we looked at the potential contribution of geography to the emergence of a local climate for innovation. One of our hypotheses for Taguspark was that articulation of its microgeography and other measures for stimulating the interactions among local actors lends more significance to the patterns of coupling and clustering.

Miscellaneous

Entry of actors

38 With certain frequency new actors were allowed to enter the population.

Exit of actors

39 Actors that did not meet the pressure to innovate exited from the population. In INTERSECTIONS exiting occurred if an actor had not innovated over a certain space of time.

Erosion of social ties

40 Social ties among actors may not persist (e.g. a key contact leaves the firm). In INTERSECTIONS we included a small chance for links in the social network to break down.

3. Modeling Concepts

Agents

Agent types

41 In INTERSECTIONS, there are two types of agents: actors and events.

Actors

42 The simulated S&T park is a dynamic network of interacting actors with links that represent social ties among actors. New actors may enter the population and resident actors may exit the sytem.

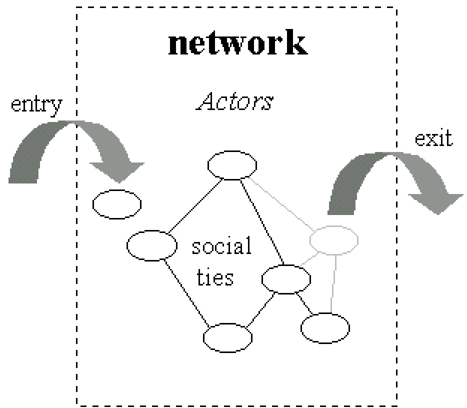


Figure 8 The simulated S&T park can be viewed as a dynamic network of interacting actors, with links representing the social ties among actors

Events

43 The interactions in the agent population included encounters among actors. For control when and where these encounters happened, a second type of (non-persistent) agents is used, called "events". Instances of events may create new or strengthened social ties among actors.

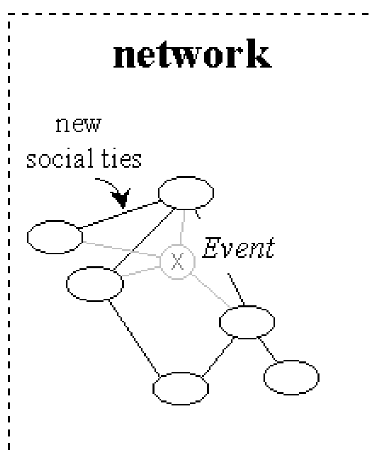


Figure 9 Events control where and when actors encounter each other, and whether or not new or strengthened social ties result

Agent types (definitions)

44 A complete description of both types of agents follows:

Agents	
Actors	• Actors are agents that represented entities involved in the innovation process like firms, policy actors, universities, research laboratories, etc. • Actors have links (social ties) with other actors. • Actors have coordinates in geographical and technological space (see Medium). • Actors interact with other actors (see Agent Behaviours). • New actors can enter the population, and actors can exit. • Social ties among actors may not persist.
Events	• Events are agents (*) that represent settings (conferences, restaurants, etc.) where encounters among actors may occur. • Events have no activities other than establishing links among (participating) actors. • Events have coordinates in geographical space and some in technological space (**) that determine their impact.

(*) The advantage of using events that were agents is that we could simulate encounters between actors without having to simulate movement of actors.
(**) Not all events had coordinates in technological space. An example of an event that hád is a "conference", with coordinates representing its topics or theme.

The Medium

Coordinates of agents

45 The agents lived in a medium that was composed of a geographical space and a technological space. Agents had coordinates in both spaces; we called them the agent's location (geographical space) and the agent's kene (technological space).

Trajectories of agents

46 Both spaces were linked with the temporal dimension. We thought of the actors following "trajectories" in both spaces over time such as an actor moved to a different location or an actor acquired new skills and technologies.

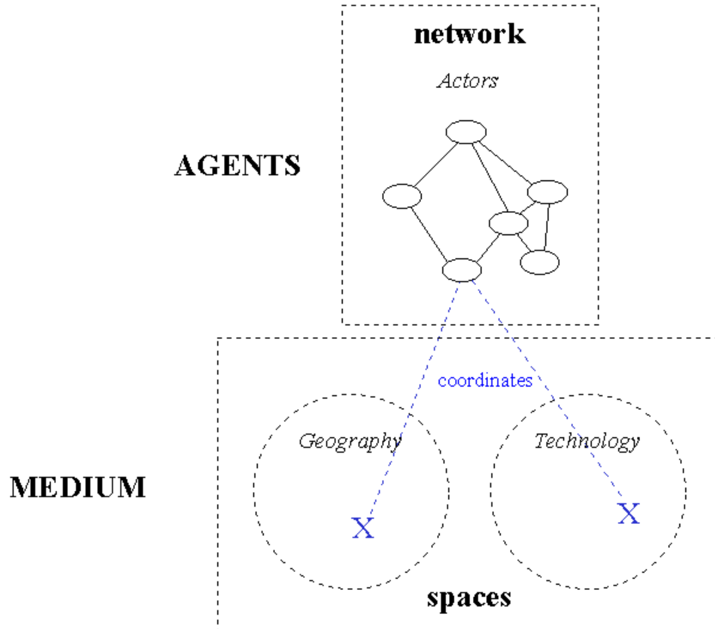


Figure 10 Agents live in a medium composed of two spaces in which their coordinates change over time

Medium (definitions)

47 A complete description of the medium follows:

The Medium	
Geographical & Technological Space	• The medium contained a geographical space and a technological space. • The representation of each space was a break down of the world into a hierarchy of increasingly specific groups (*). • The coordinates of each agent (actor or event) in geographical space pointed to a specific group (the agent's location); the coordinates of each agent in technological space may have pointed to more than one specific group that were collectively called the agent's kene. • These spaces were linked with the temporal dimension; we thought of actors following trajectories in both spaces over time, such as an actor that moved to a different location or an actor that acquired new skills and technologies. • No spatial and temporal scales were assumed a priori (**). • Geographical and technological spaces were used to conceptualize distance among agents based upon geographical proximity or compatibility of skills and technologies.

	• Distances among agents depended on group membership(s); for both spaces "distance functions" were defined.
Temporal Dimension	Time played a role in our simulations through the activation, during each time step, of a small number of agents; the activities of these agents introduced changes in the rest of our model.

(*) Consider the observation in Duncan Watts et al. (2002) about how people tend to perceive complex environments: "Individuals break down, or partition, the world hierarchically into a series of layers, where the top layer accounts for the entire world and each successively deeper layer represents a cognitive division into a greater number of increasingly specific groups."
(**) Geographical and technological spaces are "relative spaces":

- With the concept of relative space, or the relative concept of space (vs. the absolute concept of space), we tried to conceptualize the processes and mechanisms in space rather than the space itself.
- Relative spaces are defined by objects and processes under study, rather than defining them.
- When one is dealing with processes and mechanisms, space and time become properties of those processes or mechanisms under investigation. Therefore, the study of a process cannot, a priori, assume certain spatial and temporal scales.

Agent Behaviours

Agent behaviours

48 The behavioural repertoire of agents was defined through two types of strategies: actor strategies and event strategies.

Agent Behaviours	
Actor Strategies	• Actor strategies describe how actors interact with other actors. • Actor strategies typically use information about: - a particular actor's links with other actors; - the actor's distance from other actors in geographical and/or technological space. • Actor strategies typically have an impact on: - a particular actor's links with other actors; - the actor's coordinates in geographical and/or technological space.
Event Strategies	• Event strategies described how events exercise impacts on the links among actors. • Event strategies typically used information about a particular event's distances with actors in geographical and/or technological space, e.g. for identifying the event's participants (*).

(*) We also considered actors to be "participants" in case of events like accidental encounters.

Actors and Events

<u>Actor types</u>

49 There are two types of actors: "institutions" and "firms".

Actor Types	
Institutions	Institutions were universities, research laboratories, etc.
Firms	Firms varied in size from very small microfirms with no more than three employees, to firms with up to forty employees.

<u>Event types</u>

50 There are two types of events: "meetings" and "encounters".

Event Types	
Meetings	• Meetings were settings for formal, staged encounters among actors, or among people representing actors (*), such as conferences, seminars, etc. • Meetings had coordinates both in geographical space (location) and in technological space (representing topics or a theme). • Meetings typically involved a large number of actors.
Encounters	• Settings for informal, accidental encounters like restaurants, libraries, etc. • Encounters had coordinates in geographical space (location). • Encounters typically involved only a small number of actors.

(*) In our abstract world, we allowed ourselves to think of actors sometimes as entities (firms, institutions, etc.) and in other contexts as people. On a similar note, events were understood as settings for encounters to take place or the encounters themselves, again depending on the context.

Actor Strategies

<u>Actor strategies</u>

51 Four strategies were defined for actors: "Pioneer", "Imitate", "Collaborate" and "Seek Partner".

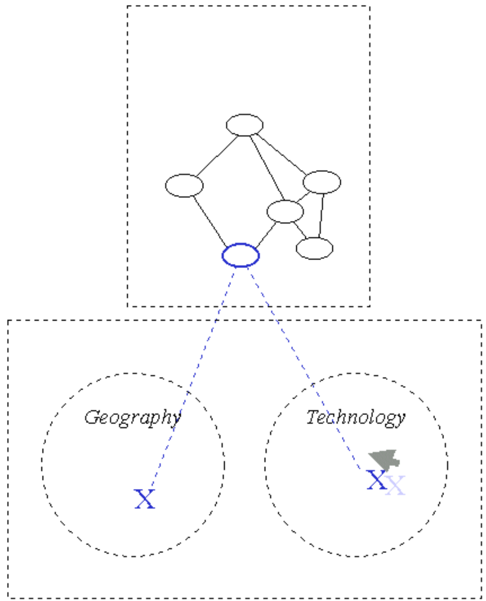


Figure 11 "Pioneer" is a go-it-alone innovation strategy that results in a slight change of the actor's coordinates in the technological space (its kene)

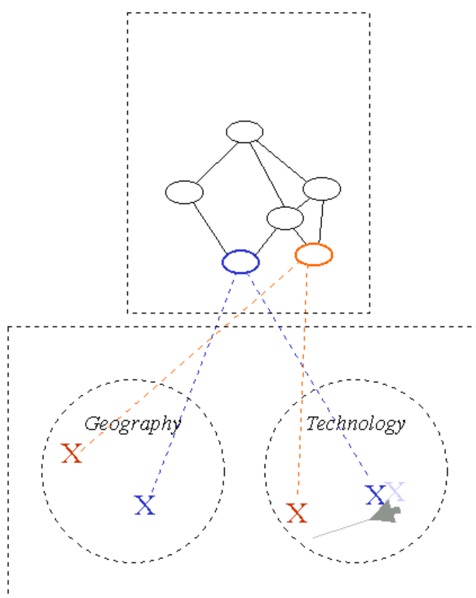


Figure 12 "Imitate" is an innovation strategy that results in a slight change of the actor's kene in the direction of another actor's coordinates

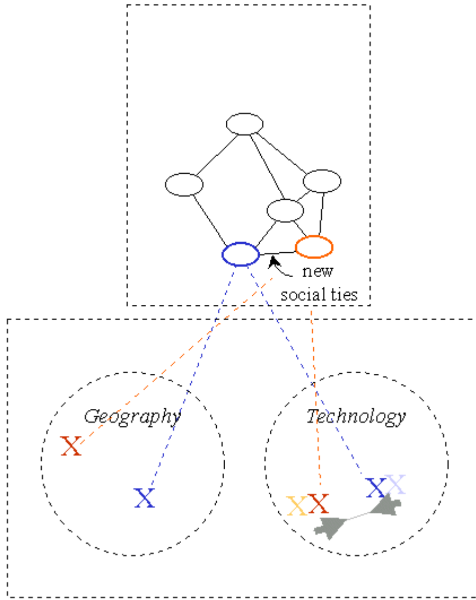


Figure 13 "Collaborate" is an innovation strategy that results in a slight change of coordinates of both actors in the technological space (their kenes), each in the direction of the other actor's coordinates, and also new or strengthened social ties between both actors

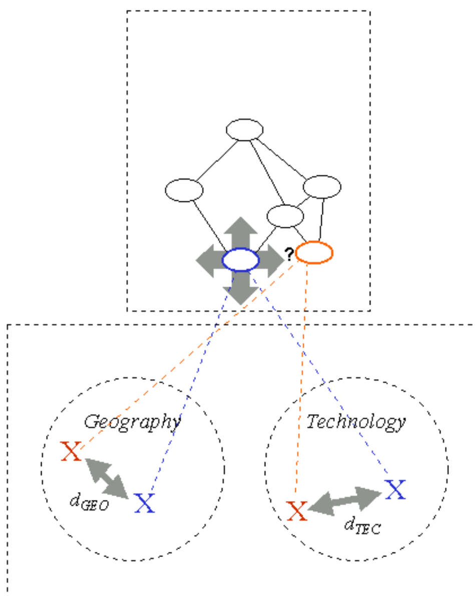


Figure 14 "Seek Partner" is a strategy called by "Imitate" and "Collaborate" to identify potential partners based on distances in the geographical and technological spaces

Actor Strategies	
"Pioneer"	• "Pioneer" is a go-it-alone innovation strategy; no other actors are involved. • The result is a slight change of a particular actor's coordinates in technological space (its kene).
"Imitate"	• "Imitate" is an innovation strategy that involves another actor, the "partner" (*). • The result is a slight change of the actor's coordinates kene in the direction of the other actor's coordinates.
"Collaborate"	• "Collaborate" is an innovation strategy that involves interactions with another actor (partner). • The results are: - a slight change of coordinates of both actors in technological space (their kenes) each in the direction of the other actor's coordinates; - new or strengthened social ties between both actors.
"Seek Partner"	• "Seek Partner" is a strategy called by "Imitate" and "Collaborate". • "Seek Partner" identifies potential partners for these strategies. • Potential partners are identified based on distances among a particular actor (the "seeker") and other actors in geographical and technological space. • The result is the "most attractive" potential partner.

(*) We considered actors to be "partners" even if they had a passive role in the interaction.

Event Strategies

<u>Event strategies</u>

52 Two strategies are defined for events: "Seek Participants" and "Create Social Ties".

Event Strategies	
"Seek Participants"	• "Seek Participants" is a strategy for identifying participants in a particular event. • Participants are identified based on distances between the event and actors in geographical and (if applicable) in technological space. • The result is a group of participants, with the constraint that the group size must be kept within the limits set for the event.
"Create Social Ties"	• "Create Social Ties" is a strategy that produces the event's impact on the social ties among actors. • The result is the creation of new or strengthened social ties among participants established during the event.

4. Overview: A Complex Virtual World

Complex systems consist of multiple elements that adapt or react to the patterns that these elements create. The relations that were conceptualized up to this point can be depicted in five diagrams: Figure 15 through Figure 19. The figures show that the virtual world that the team created with INTERSECTIONS was indeed a complex system.

(The numbers in circles ①, ②, ③ and ④, in the left margin, refer to items in the diagram.)

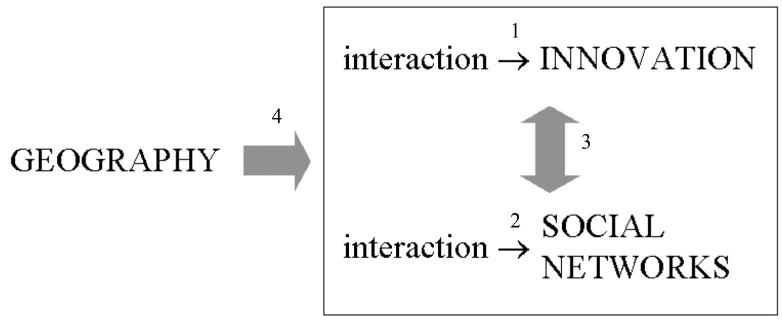


Figure 15 The focus of the application of INTERSECTIONS for Taguspark (same as Figure 7)

Main Processes

① Interactions → Innovation: Driven by an exogenous pressure to innovate, actors interact (imitate, collaborate) with the goal to update their skills and technologies.

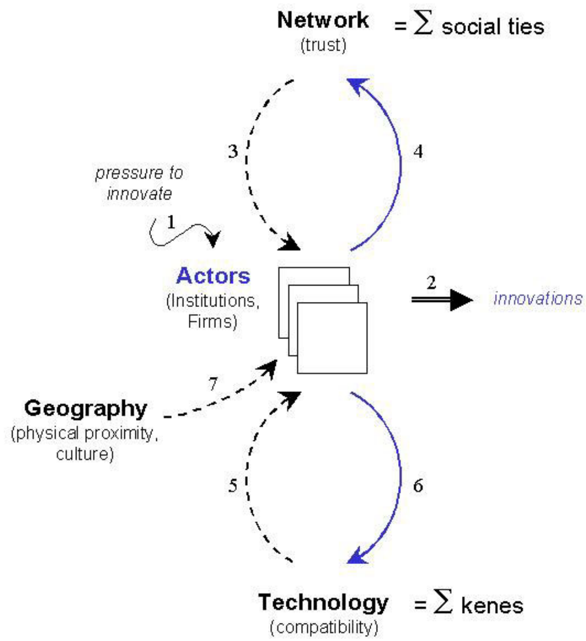
② Interactions → Social networks: Driven by sociality, actors meet with other actors (either intentionally or accidentally) with the result that new or strengthened social ties are established and trust is built.

③ Innovation ↔ Social networks: ① and ② are intertwined: collaborative efforts to innovate resulted in new or strengthened social ties between the actors involved. Reversely, social ties between actors implied trust and increased opportunities for imitation or collaboration.

④ The roles for geography: For the taguspark case study, we examined the role of geography, with a special interest in the potential contribution of geography to the emergence of a (local) climate for innovation.

Each item in Figure 15 is elaborated in the diagrams that follow.

Interactions → Innovation



A solid arc from A to B stands for: "The strategies of A that have an impact on B"
A dashed arc from A to B stands for: "A influences B's choice of strategies"

Figure 16 Elaboration of Interactions → Innovation

Pressure to Innovate

① Pressure to innovate: INTERSECTIONS was not designed to provide an elaborate answer to the question: WHY innovation? It simply assumes an exogenous pressure to innovate to which all actors are (equally) exposed.

Technologies and Compatibility

Technology = Σ Kenes: Innovation is understood as the successful exploitation of new ideas, yet we gave exclusive attention to one part of the innovation process: how actors update their skills and technologies. For this, we used the concept of a "kene".

Compatibility: The extent to which the variety pool of kenes constitutes a potential for innovation was captured by our notion of “compatibility”. Our notion was based on the idea that potential innovation partners should have "compatible" kenes; meaning "they should not be too similar and not too different". In INTERSECTIONS a distance function was used to calculate distance between any two kenes, which then could be compared to lower and upper limits of compatibility.

Social Networks and Trust

Network = Σ Social ties: Social networks can contain many kinds of links, yet in INTERSECTIONS linkages were limited to “social ties” between actors

Trust: In INTERSECTIONS, creation of social ties implied trust building. There was no explicit representation of trust between actors; we considered trust to be fully captured by the configuration of the social network. Trust is important because it facilitates the interaction between actors for innovation.

Erosion of social ties: Social ties tend to erode and breakdown unless actors strengthen them from time to time. In our simulations with INTERSECTIONS, during each time step, there was a small chance of one or more links in the network breaking down.

Innovations and the Innovation Process

② Innovations: In INTERSECTIONS innovations are instances of mutations or recombinations of kenes.

Innovation strategies: Mutations of kenes occur when actors decided to go-it-alone and innovated following a pioneer strategy. Crossovers between kenes are the result of innovation strategies Imitate or Collaborate that involve interaction between actors. The impact of each innovation strategy:

⑥ "Pioneer" is a go-it-alone innovation strategy that results in a slight change of the actor's coordinates in technological space (its kene).

⑥ "Imitate" is an innovation strategy that results in a slight change of the actor's coordinates in technological space (its kene) in the direction of another actor's coordinates.

④⑥ "Collaborate" is an innovation strategy that results in:
- a slight change of coordinates of both actors in technological space (their kenes) each in the direction of the other actor's coordinates;
- new or strengthened social ties between both actors.

Seeking a partner for innovation: "Seek Partner" is a strategy used by Imitate and Collaborate.

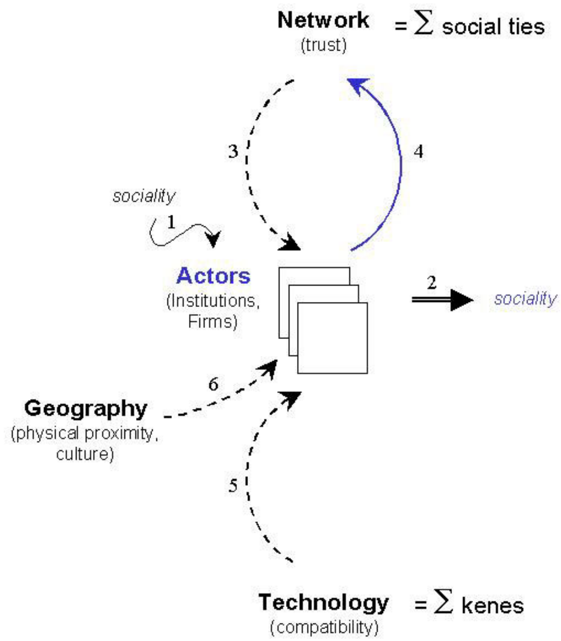
③ Social ties between actors imply trust, making socially connected actors more attractive as potential partners (even when they are too different to be compatible in a strict technological sense). The strategy results in identification of the "most attractive" (potential) partner.

⑤ Attractive potential partners are identified based on distances between a particular actor, the "seeker", and other actors in technological space (i.e. compatibility).

The Roles of Geography

⑦ Geography and innovation: Physical proximity implies trust (e.g. a shared cultural background) and increased opportunities for innovation. The impact of geographical proximity is similar to that of social ties (see ③).

Interactions → Social Ties



A solid arc from A to B stands for: "The strategies of A have an impact on B"
A dashed arc from A to B stands for: "A influences B's choice of strategies"

Figure 17 First elaboration of Interactions → Social Ties, with the actors put in the centre

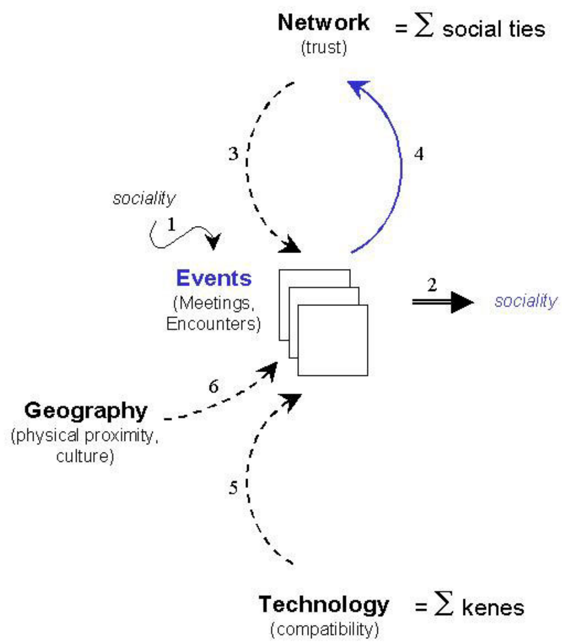
Sociality

① <u>Actors and sociality</u>: New or strengthened social ties between actors can be established when actors (or rather, people representing them) physically meet at a certain location. These interactions are driven by people's motivations, habits, etc. that as a whole we refer to as "sociality". In INTERSECTIONS we treat sociality as an exogenous driver, i.e. we do not aim to provide an elaborate answer to the question: why sociality?

② <u>Sociality and feedback</u>: An interesting aspect of sociality is that the result of these interactions is more sociality, which constitutes a positive feedback loop.

(See Figure 18 for the explanations of the other items.)

For the elaboration of the other items in Figure 17, events replace actors in the centre of the figure.



A solid arc from A to B stands for: "The strategies of A have an impact on B"
A dashed arc from A to B stands for: "A influences B's choice of strategies

Figure 18 Second elaboration of: Interaction → Social Ties, with the events put in the centre

Events and Social Ties

Events: From a modeling point of view, it was more convenient to simulate the interactions between actors driven by sociality using a new kind of agents: "events". This way, we could circumvent the burden of having to model movements of actors, while still being able to take into account the geographical locations of actors. In INTERSECTIONS events are instances when two or more actors (or rather, people representing them) physically meet at a certain location.

Meetings and encounters: Two types of events were distinguished:
"Meetings" are instances when actors meet at formal, staged encounters, like conferences.
"Encounters" are instances when actors meet in informal, accidental encounters, for example when people start a conversation while queuing in a restaurant.
Their distinction is important because the impact of on the network is different for the two types of events:
④⑤ Meetings, like conferences, attract actors that are proximate in technological space, and they, contrary to encounters, may result in new or strengthened social ties between actors that are distant in geographical space.
④⑥ Places for encounters, like restaurants, attract firms that are proximate in geographical space, and they, in contrast to meetings, may result in new or strengthened social ties between actors that are distant in technological space.

Event strategies: Two strategies are defined for events: Seek Participants and Create Social Ties.

⑤⑥ Seek Participants is a strategy for identifying participants in a particular event. Participants are identified based on distances between the event and actors in geographical or in technological space depending on the type of event. The result is a group of participants that interact … with the constraint that group size must be kept within the limits set for the event.

④ Create Social Ties is a strategy that produces the event's impact on links between actors. The result of the strategy is the creation of new or strengthened social ties between participants that are established during the event.

The Roles for Geography

⑥ Geography and encounters: With our notion of encounters, we mirrored the fact that actors that were geographically proximate were more likely to physically meet each other on an informal, accidental basis. This way, actors that were geographically proximate were more likely to establish new or strengthened social ties than actors that were geographically distant.

Overview

Figure 16 and Figure 18 are combined in Figure 19.

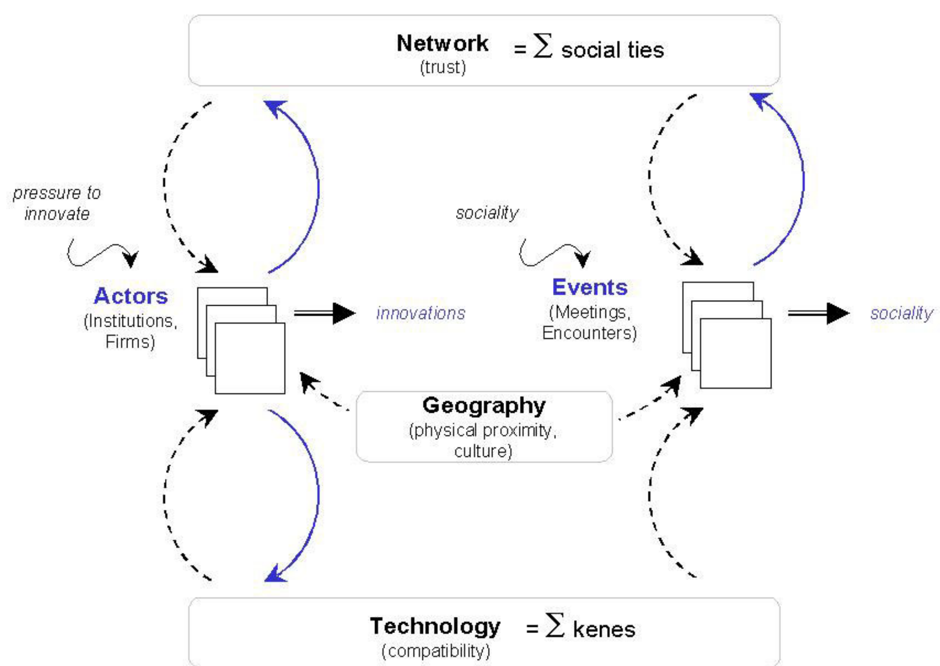


Figure 19 Overview of the relations in the INTERSECTIONS model. The virtual worlds that can be created with INTERSECTIONS are complex systems consisting of multiple elements (actors and events) that adapt and react to the patterns that these elements create, including the patterns in the geographical and technological spaces and the evolving topologies of social networks.

APPENDIX B PART 3, LISBON CASE STUDY

REFLECTIONS ON THE EXPERIMENTAL DESIGN

1. Introduction

Generally speaking, the experimental design is a creative process that involves a number of steps, some of them implicit, to develop hunches into simulated experiments. Specifically, six steps for experimental design are proposed in this thesis:

Step 1: Select building blocks;
Step 2: Produce perspectives;
Step 3: Define models;
Step 4: Conduct experiments;
Step 5: Produce scenarios;
Step 6: Evaluate building blocks.

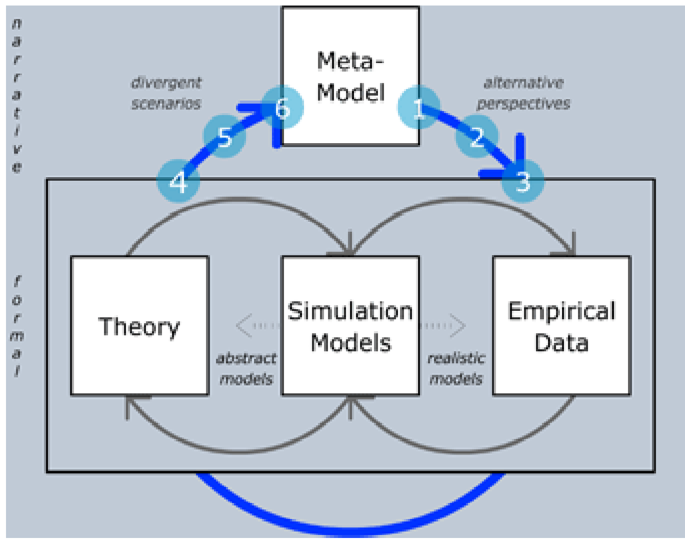


Figure 20 Overview of the Experimental Design framework

What follows is a reflection on the experimental design that eventually resulted in the development of the INTERSECTIONS model. The goal of this reflection is to determine the match between the proposed six explicit steps and the implicit/explicit steps that were taken by the research team.

2. Reflections on the Experimental Design

Step 1: Select Building Blocks

- The team developed and used a meta-model for building an axiomatic base. See Figure 22.
- Besides a review of tools for agent-based simulation[19] the team had made no effort to formulate requirements that would apply to the model definition.

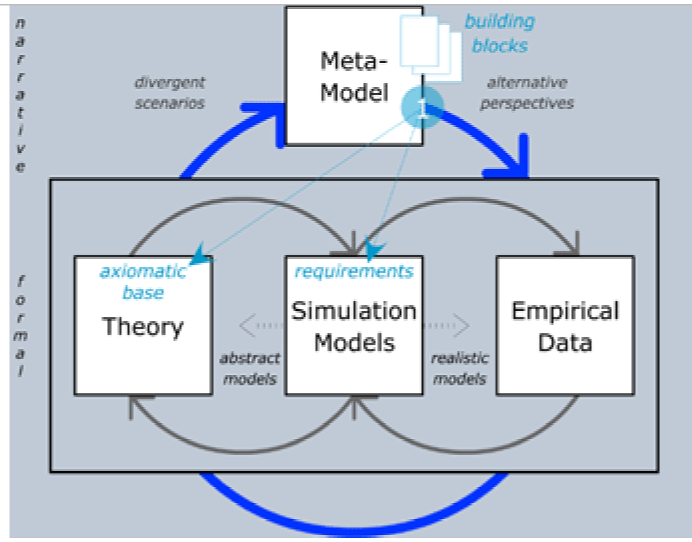


Figure 21 Step 1: Select building blocks

[19] The Swarm toolkit (www.swarm.org) was picked mainly because of the possibilities that this toolkit offers for simulations with large populations of agents in spaces that can be easily observed. Moreover, the toolkit provides good demo applications that show how to build such simulations.

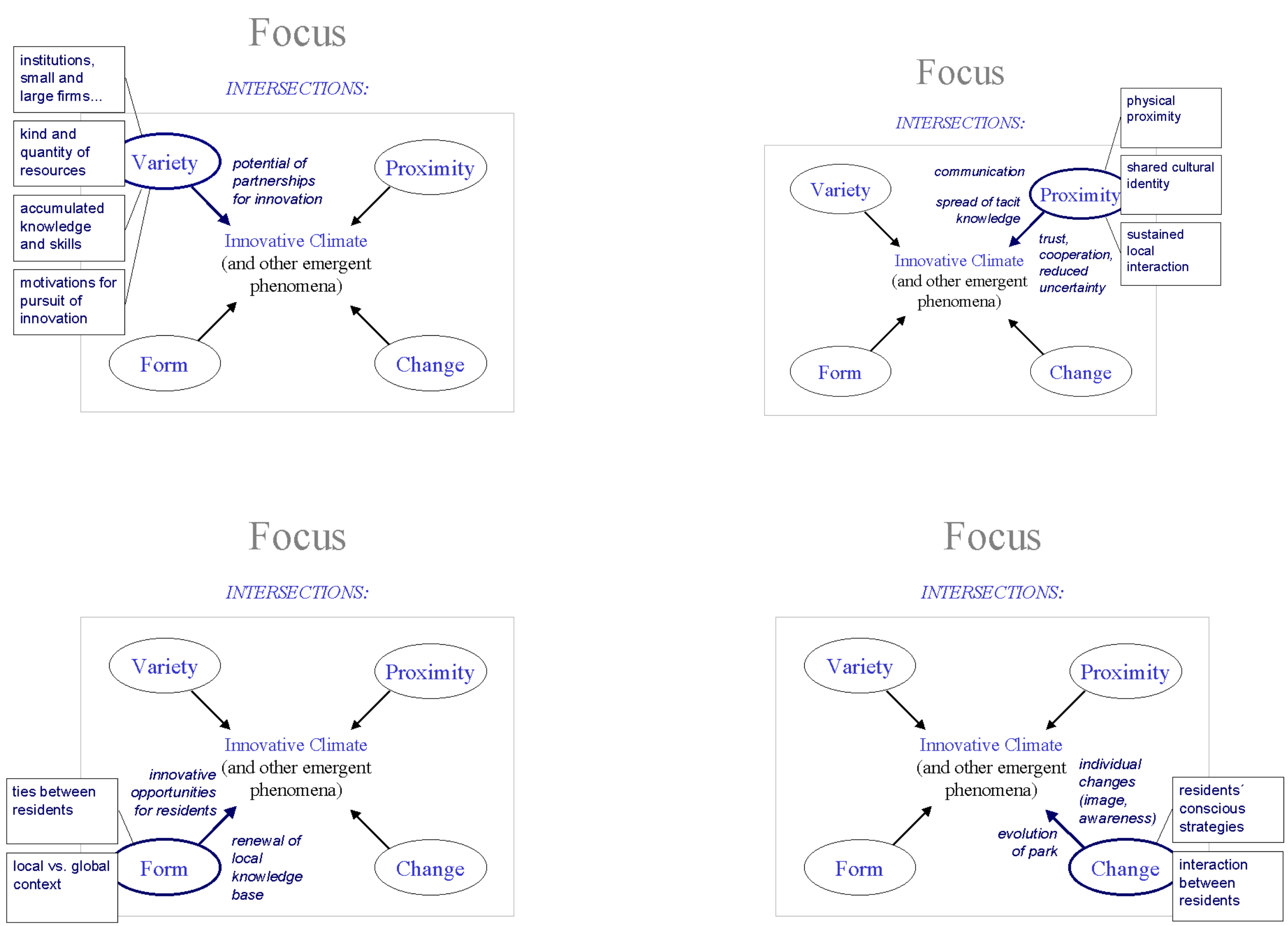


Figure 22 The meta-model contained axioms on the role of variety, proximity, form and change

Step 2: Produce Perspectives

- An important vehicle for producing perspectives was the early prototype. See Figure 24.
- A survey was conducted in Taguspark, with interviews with people from 30 in-park firms. The focus of the questionnaire was broad and was based on the complete meta-model.
- After the survey data had been analysed, the team started collaborating more intensely in order to elaborate their hunches and start producing alternative perspectives.
- After elaboration three hunches remained in competition. These hunches were written in the format of a question and hypothesized answer. See Figure 25.

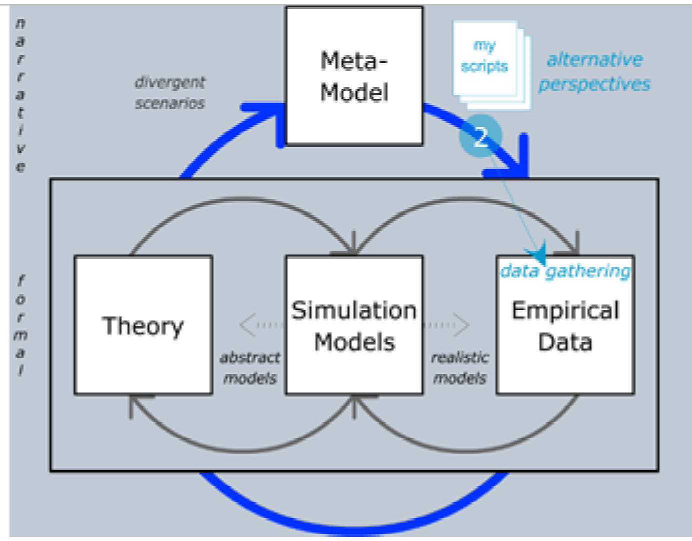


Figure 23 Step 2: Produce perspectives

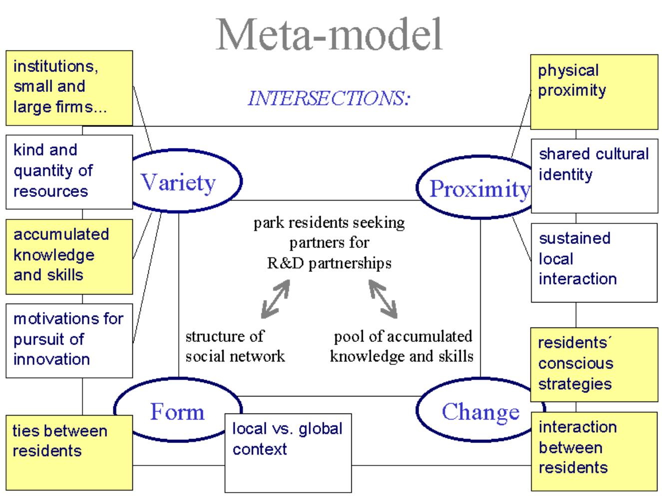


Figure 24 A selection of axioms (highlighted) led to the tool's prototype, described in the centre

Hunch #1: Microgeograhpy

Question:
What can be improved to stimulate the interaction between people and firms within the Taguspark?

Answer:
Reconsider the locations of firms, restaurants, libraries, etc., using principles from urbanism, like techniques for grouping. For example, integrate:

- the planning of clusters of firms that respect some diversity;
- the planning of centers that attract people to spend time there.

Take into account:

- the quality of a location (looking at ecology, comfort, etc.);
- the diversity in a cluster (looking at technological areas);
- the polarity of a centre (looking at combinations like restaurant + services, library + place for reading + place for having coffee, etc.).

Hunch #2: Missing Ingredients

Question:
What "ingredients" are missing in the "mix" that we see in the Taguspark?

Answer:
Looking at the Taguspark the team identified:

- entities that already have been established, but do not function yet to full potential, such as:
    - universities;
    - R&D institutions;
    - the support to business initiatives;
- entities that are still lacking, such as:
    - anchor entities; big firms or public entities that have overarching impact on park;
    - public "operator" for the articulation of firms already installed;
    - the support of the business network, like a local productive system.

Hunch #3: Microfirms

Question:
What can the Taguspark do to help microfirms make the step from passive to pro-active innovation behaviour, in other words, to become "innovative"?

Answer:
Microfirms need to secure their access to (new) markets and access to (new) knowledge. They should find answers to three questions:

- What will our clients demand in the near future?
- What technologies will be available in the near future?
- How can we be a broker between the two (clients and technology) in the midst of these changes?

To find these answers and to innovate accordingly will require an ongoing effort (R&D and marketing) that can only be successful if it is nurtured by the firm's social network and its sources for finance. It is here where the Taguspark can help: provide access to valuable contacts and to funding for innovation, not only during a microfirm's startup, but also beyond.

Figure 25 The three hunches that remained in the competion

Step 3: Define Models

- Due to time limits, only one model could be defined and developed for the team's first hunch: "Microgeography".
- This meant that there was no competition among models.
- There were several reasons for picking this particular hunch and leaving the other two:
    - It was closest to the initial project formulation and objectives.
    - It could be straightforwardly implemented by developing the prototype further.
    - It was necessary to establish the "fundamental dynamics" (i.e., the interlinked processes of technological evolution and social interaction) before other hunches could be explored.

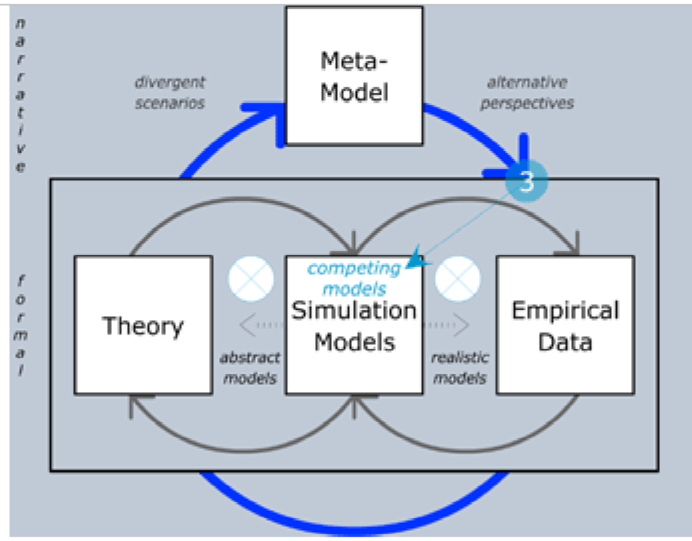


Figure 26 Step 3: Define models

Step 4: Conduct Experiments

- The model was implemented in Swarm and many runs were performed looking at a broad range of possible choices of parameter values.
- The experiments were then concentrated on the different types of "connectivity" that may govern the evolution of social networks in the park. These experiments served to develop and test alternative schemes for the articulation of the park's microgeography.
- The rationales for these schemes were developed on the basis of two hypotheses:
  1. A climate for innovation is more likely to emerge if the evolution of social ties among in-park firms is governed by "small world" connectivity.
  2. Certain environmental factors in the park, constituted by infrastructures, "attraction points" and "corridors", can contribute to the eventual presence of such network connectivity.

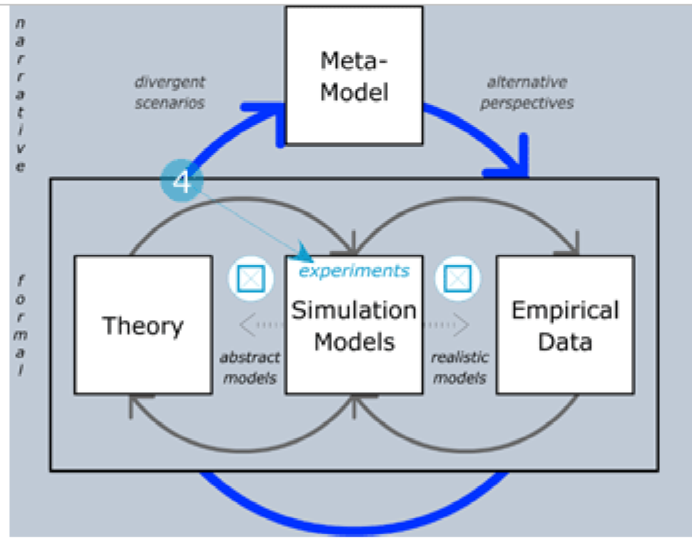


Figure 27 Step 4: Conduct experiments

Step 5: Produce Scenarios

- Based on results with experiments two types of scenarios were produced:
  1. The "base" scenario demonstrated that a climate for innovation will not emerge "naturally" as a consequence of "social time". The team considered this scenario representative for the actual situation in the Taguspark.
  2. The "would-be" scenarios showed that articulation of the park's microgeography and improvement of the park's environmental factors can increase the likelihood of the eventual emergence of a climate for innovation.

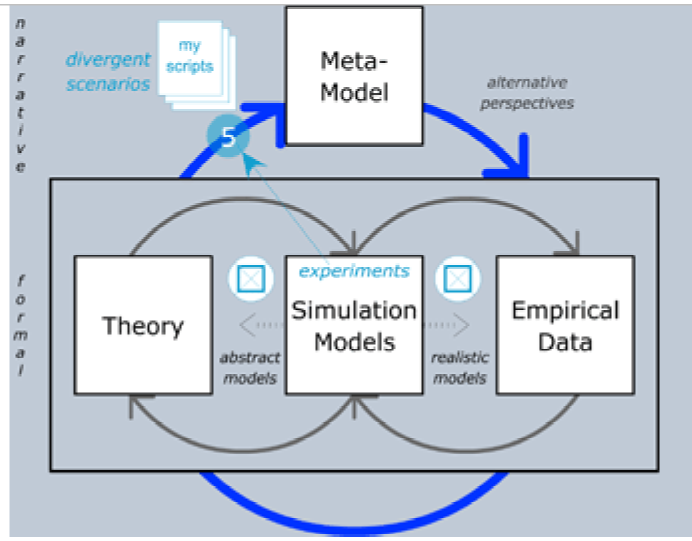


Figure 28 Step 5: Produce scenarios

Step 6: Evaluate Building Blocks

- There has not been a moment for the team to evaluate the direction that the experiments were taking. However, there have been several moments when suggestions were made:
  - A general tendency was to question the high level of abstraction in the model. Yet others regarded this to be a strength of the model.
  - For example, repeatedly questions were raised by team members and others about why there was no "reward mechanism" built into the model. The most obvious example of such mechanisms is that firms are being rewarded with profits for the successful exploitation of an innovative idea.
  - Without exception, kenes were considered a useful concept.
  - Several team members had difficulties with appreciating the model's emphasis on contingencies, with firms reacting and adapting on patterns rather than rationally deciding and anticipating innovation strategies. The emphasis on contingencies has its roots in the building blocks that were picked in step 1.

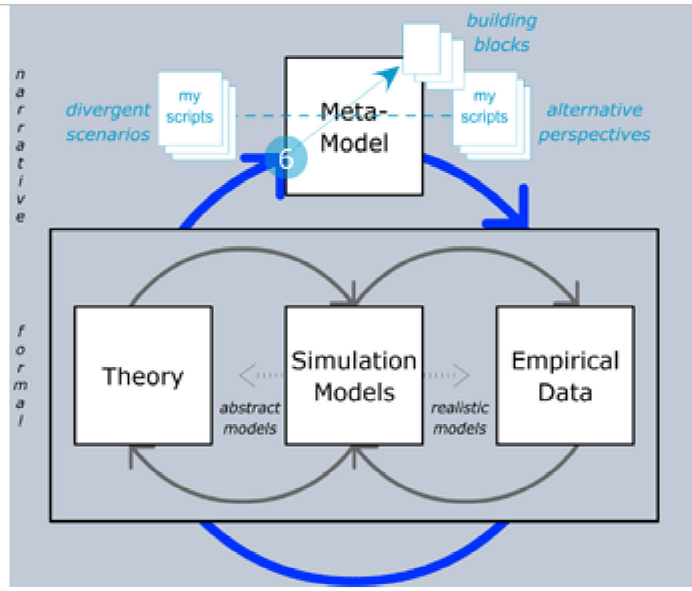


Figure 29 Step 6: Evaluate building blocks

APPENDIX B PART 4 LISBON CASE STUDY

EVALUATION OF THE BUILDING BLOCKS APPROACH

1. Introduction

The experiences with INTERSECTIONS were used to test the Building Blocks Approach that is proposed in this thesis (in Appendix A.2). This approach involves the creation and application of "webs" of conceptual "building blocks" that show interconnections among theories. Webs of building blocks can help modeling teams assemble alternative "blueprints for synthesis" that lead up to diverging experiments with agent-based simulation models.

The test covered three main questions:

1. Do the steps in the actual development process for INTERSECTIONS correspond with the proposed approach for using building blocks?
2. Would the results be the same?
3. Do the experiences with INTERSECTIONS point to limitations for application of the building blocks approach? In particular, do data requirements or other considerations for implementation pose restrictions that limit its applicability?

Before these three questions could be answered and the building blocks approach could be tested, one more question had to be answered first: Which combinations of building blocks match the actual conceptualization of the INTERSECTIONS model?

2. Evaluation

Theme: Integration

First, consider building blocks for the theme "Integration". The conceptualization of INTERSECTIONS was matched by a combination of three building blocks:

- Creativity and Innovation;
- Agency for Change;
- Individual Change.

These building blocks are shown in Figure 30.

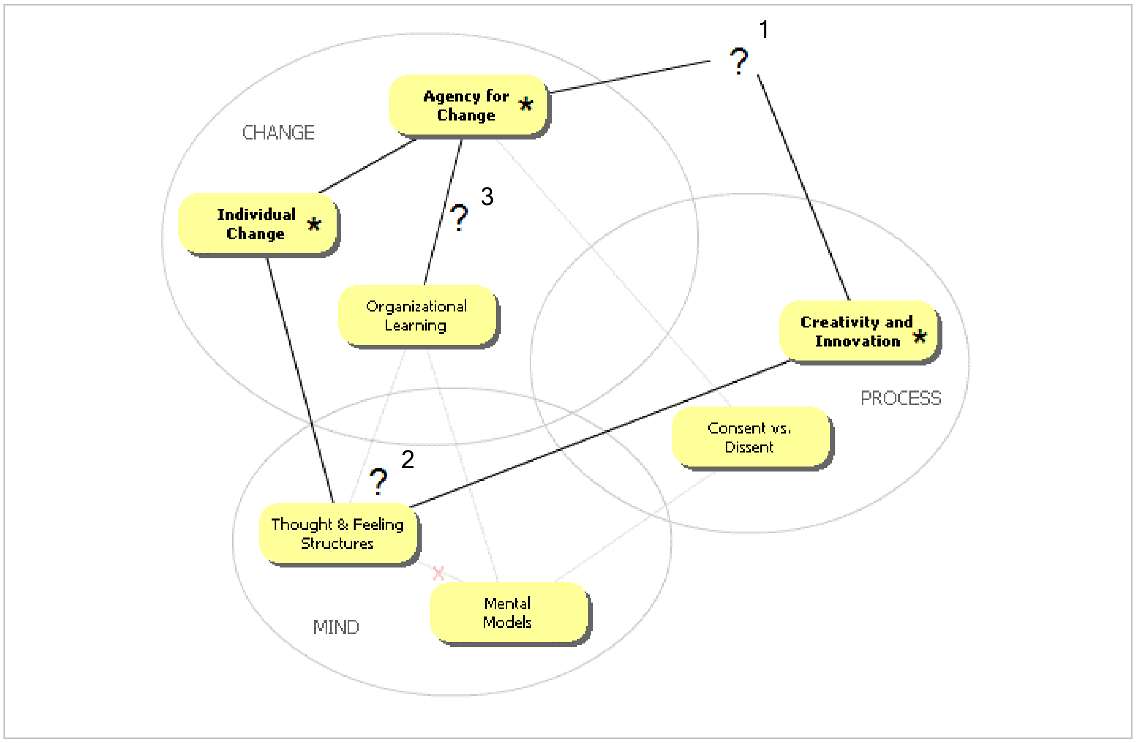


Figure 30 Building blocks from the theme "Integration"

What more does Figure 30 show?

(The numbers in circles ①, ② and ③, in the left margins, refer to items in the diagram.)

Missing links

① INTERSECTIONS suggests a link between Creativity and Innovation and Agency for Change, however this link is not clarified in the diagram.

② The diagram also does not give clues about the link between Creativity and Innovation and Individual Change other than through Thought & Feeling Structures, which is beyond the current focus of INTERSECTIONS.

New links

② The concept of "trust" can be useful to establish the link between Creativity and Innovation and Individual Change (e.g. the latter signifying either "becoming more trusting" or "becoming more trustworthy"). In INTERSECTIONS, trust is conceptualized in an implicit way (i.e. implied by social ties, geographic proximity, and a shared cultural background). The concept could however be made more explicit.

② Similarly, it would be possible to express the link between Creativity and Innovation and Individual Change through Mental Models. To this end, certain cognitive properties can augment the definition of (reactive/adaptive) agents in INTERSECTIONS.

①③ One team member's interest was in adopting the "immune system perspective" (that is described after this). This perspective could help to express the link between Creativity and Innovation and Individual Change through Organizational Learning, and perhaps also give clues about the missing link between Agency for Change and Creativity and Innovation.

The "immune system perspective" deserves more attention here because it exemplifies the "out of the box" thinking that is stimulated by the Building Blocks Approach.

The Immune System Perspective

The immune system perspective is a potentially interesting perspective for studying the patterns of interactions that correspond to a (local) climate for innovation. The overarching hypothesis is that science and technology (S&T) parks share a number of similarities with biological immune systems, including:

- The ability to recognize harmful invasions;
- The ability to design measures to control and destroy these invasions;
- The ability to remember successful response strategies.

To test whether these similarities actually exist, specific questions need to be asked.

Pathogens: Immune systems are subject to constant invasions:

- What are harmful human invasions for S&T parks?
- What are harmful technological invasions?
- What are harmful cultural invasions?

Detection: The detection of pathogens focuses on the identification of harmful nonself pathogens. Detection of harmful invasions by an immune system depends on knowledge of the system and the monitoring of particular indicators.

- What are the indicators for S&T management? Can they perform well despite delays?
- What kinds of uncertainties make detection more difficult?

Response: The immune system has a variety of alternative responses, because different pathogens require different methods of elimination. The immune system is adaptive because it is able to learn and adapt to new kinds of pathogens.

- What kind of responses can be produced by S&T parks?

Memory: A key element in the adaptivity of systems is the role and function of memory. Immune systems have a limited capacity for remembering successful responses; its memory needs to be kept up to date.

- Is there a role and function of memory in S&T parks? If so, how does it work?

Maintenance: The functioning of an organism's immune system depends on the condition of the organism.

- What determines the resilience (i.e. the ability to persist despite disturbance) of S&T parks, and how can it be managed?

Literature:

Hofmeyr, S. A. 2001. An interpretative introduction to the immune system. In I. Cohen and L. Segel, editors. Design principles for the immune system and other distributed autonomous systems. Oxford University Press, Oxford, UK, in press.

Janssen, M.A. 2001. An immune system perspective on ecosystem management. Conservation Ecology 5(1): 13. [online] URL: http://www.consecol.org/vol5/iss1/art13

Theme: Complexity

Next, consider building blocks for the theme "Complexity". The conceptualization of INTERSECTIONS is matched by a combination of three building blocks:

- Order;
- Evolution;
- Self-Organization.

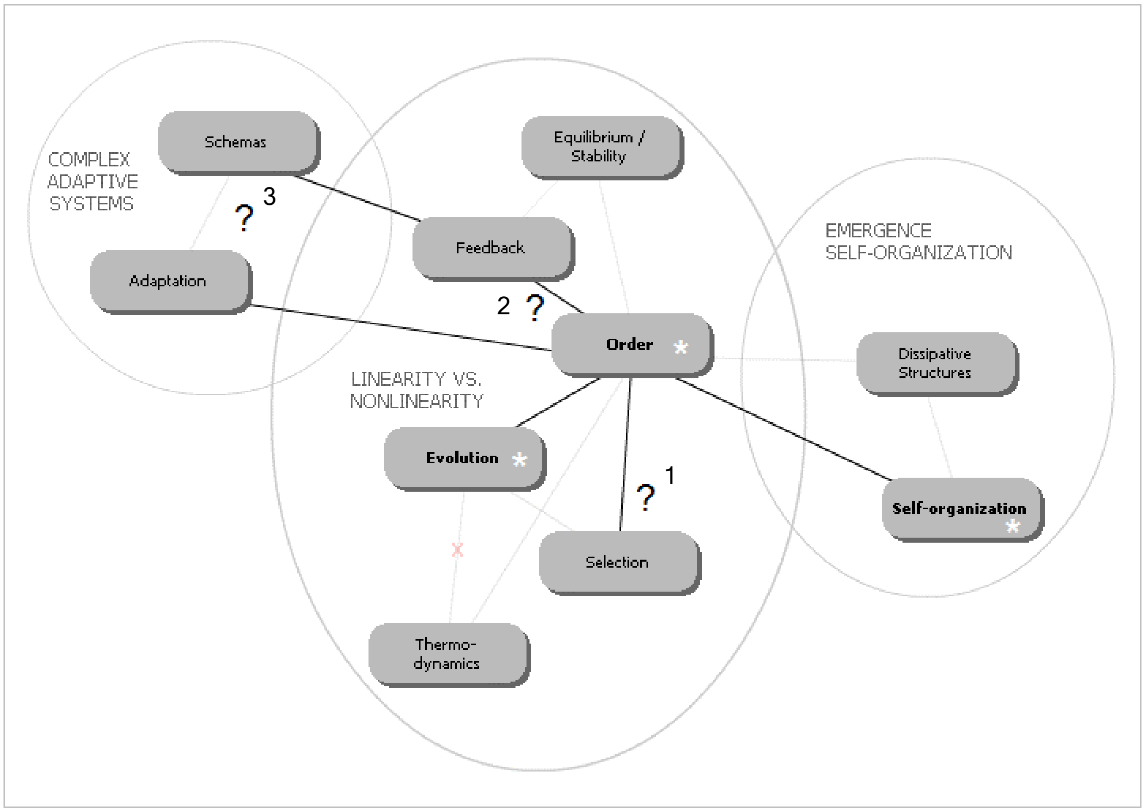


Figure 31 Building blocks from the theme "Complexity"

Missing links

There are no missing links; the links among the three building blocks are clarified in the diagram. See the link between Evolution and Self-organization through Order.

New links

①②③ An eventual incorporation of an immune system perspective would be (roughly) matched by addition of several new links that are suggested by the diagram; from Selection (e.g. of harmful invasions) through Feedback (for detection) to Adaptation (response).

Theme: Social Networks

Finally[20], consider building blocks for the theme "Social Networks". The conceptualization of INTERSECTIONS is matched by one single building block:

- Small World Property

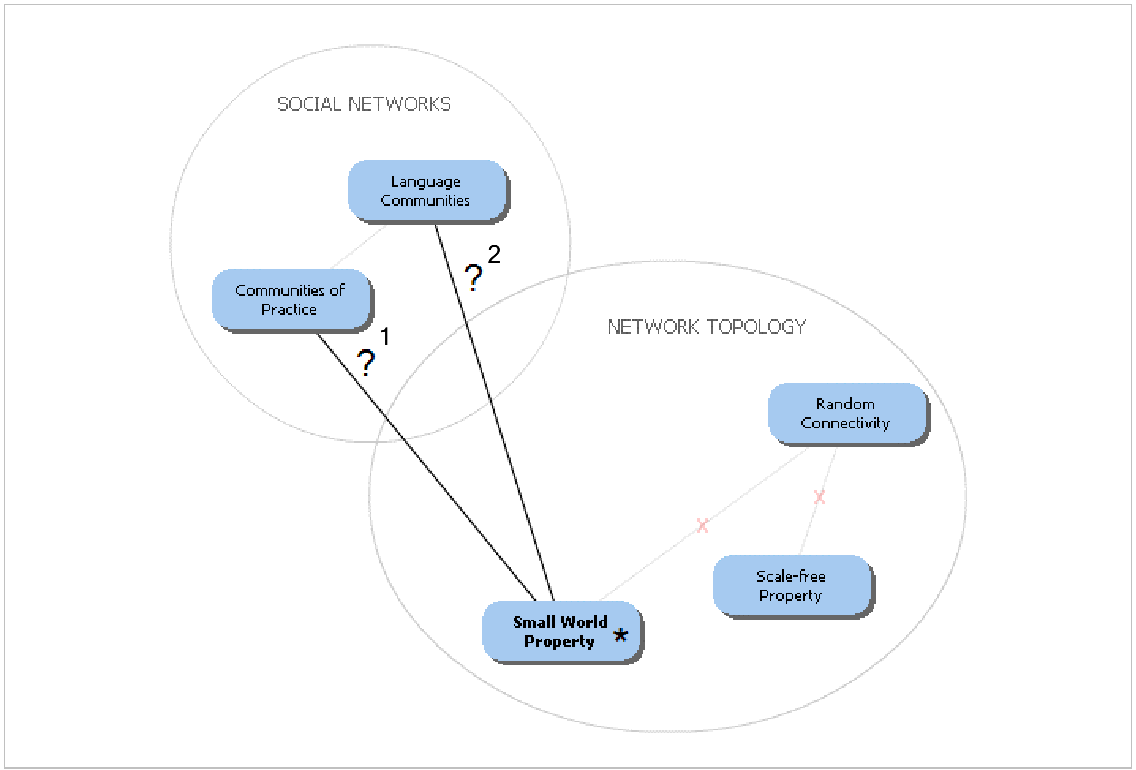


Figure 32 Building blocks from the theme "Social Networks"

New links

①② Concepts about communities, and in particular the building blocks Communities of Practice and Language Communities, can add to the perspective(s) on innovation offered by INTERSECTIONS. Their adoption would clarify how knowledge, ideas and information flow "through the social ties among firms", and when and why some of these social ties are more persistent than others.

[20] The theme "Communication" is not considered because there is no explicit conceptualization of human communication in INTERSECTIONS.

Across Themes

When considering links across themes, the building blocks approach suggests other links that are matched in INTERSECTIONS, or can be explored after some extensions, including:

- the link between Creativity and Innovation and Evolution;
- the link between Order and Small World Property;
- the link between Agency for Change and Adaptation through Organizational Learning;
- the link between Creativity and Innovation and Self-organization through Dissipative Structures;

and other links.

These "cross-links" are not further discussed here. The CD-ROM includes the Building Blocks Explorer[21] that allows the reader to find the many interesting interconnections that are possible.

[21] Choose "Building Blocks" from the main menu, then click on "Explorer" tab and navigate between the various diagrams that can be accessed from there.

APPENDIX B PART 5, PORTO ALEGRE CASE STUDY

THE RAP/RAP+ WORKSHOPS

1. Introduction

The first workshop
In the first workshop steps 1-4 of the Rapid Assessment Program were implemented. The result was a systems representation of the municipal solid waste (MSW) problem in the metropolitan area of Porto Alegre.

✓	Step 1. - Describe the problem;
✓	Step 2. - Define the objectives;
✓	Step 3. - Define the elements in the system under investigation;
✓	Step 4. - Define the interactions between these elements;
	Step 5. - Analyze and evaluate the changes as a result of strategies;
	Step 6. - Compare the various options.

The intermediary steps
To consolidate the model from the first workshop, it was necessary to complete step 5. So, between the two workshops, contributions of the participants that were still needed were gathered using e-mail.

✓	Step 1. - Describe the problem;
✓	Step 2. - Define the objectives;
✓	Step 3. - Define the elements in the system under investigation;
✓	Step 4. - Define the interactions between these elements;
✓	Step 5. - Analyze and evaluate the changes as a result of strategies;
	Step 6. - Compare the various options.

The second workshop
In the second workshop, steps 3-5 were iterated a second time. This time, participants extended the model from the first workshop with data concerning "actors" (government, institutions for learning, industries, NGOs and recyclers).

✓	Step 1. - Describe the problem;
✓	Step 2. - Define the objectives;
✓✓	Step 3. - Define the elements in the system under investigation;
✓✓	Step 4. - Define the interactions between these elements;
✓✓	Step 5. - Analyze and evaluate the changes as a result of strategies;
	Step 6. - Compare the various options.

The last step (step 6) was implemented by the consultants after the workshops, in which the most important strategies that emerged from the workshops were compared. These results were presented in a final report that was disseminated to the participants after the workshops.

The Workshop Participants

Workshop Participants

Stakeholders

Porto Alegre
Porto Alegre is well known for its progressive policies that respect themes like participative democracy and environment. The city and the state Rio Grande do Sul (of which it is the capital) do not resemble Brazil at all, but have more similarities to Europe. However, it would be too much to say that the region has a European character. From the influences of its surrounding areas (Argentine and Uruguay) and its history of immigration (German, Italian, Japanese) originates a seamless plurality that is unseen in Europe. The typical European problems with integration are not apparent yet, but a new stream of immigrants from Argentina possibly may change this. The typical climate and lifestyle ("gaucho") contribute to a strong sense of their own identity that at times culminates into separatism away from the rest of Brazil. The progressive policies of Porto Alegre are a consequence of the long period that the political party Partido de Trabalhadores (PT) ruled there, the "Labour Party"; the left wing political movement started by Brazil's current president "Lula".

Copesul
Copesul is a petrochemical company that employs about 950 and was privatised recently (it was "conceived" by the state). It produces basic chemicals from nafta, like ethene. The company has the reputation of being a good employer and it links its image with themes like worker's health and safety, environment and social engagement. Nonetheless, it produces chemicals and finds itself from time to time in tension with authorities. Although the environmental legislation and regulation in Brazil is very modern, unfortunately, things often go wrong with compliance. Responsibilities for policymaking and control are mostly with the state Rio Grande do Sul.

UFRGS
Local universities like UFRGS focus their research activities mostly on the interests of Porto Alegre and Rio Grande do Sul. This is especially because of the earlier mentioned total lack of interest on the part of industry. Along with some other universities in São Paulo and Rio de Janeiro, UFRGS enjoys a favourable reputation in Brazil.

Workshop Participants

Stakeholder Profiles(*)

Porto Alegre
The department that is responsible for implementing the policy on municipal solid waste is DMLU. It is responsible for collection, processing, and disposal. Within DMLU there is willingness to professionalize the services, but the costs of the investments needed in new technologies, acquisition of knowledge and schooling of workers are obstacles. There is no impulse for innovation mainly because of the monopoly position of DMLU. Collaboration with other departments must improve. Thinking beyond the boundaries of the municipality is necessary. This happened in a number of other interesting projects that are typical for Porto Alegre and Rio Grande do Sul.) The existing culture and perception of the organization DMLU must be changed. Price agreements and contracts with target groups such as hospitals, airports, harbours, and residences, could lead to innovation. The DMLU was recently given authority to make such agreements.

Copesul
Increasing consumption of plastics may well lead to more strict laws and regulations, which will undoubtedly harm Copesul. The company operates in fierce competition with other petrochemical companies in Brazil and abroad. For this reason Copesul chooses to act pro-actively. By taking initiative, the company can control the conditions in which the new market of plastics including the supply and demand of recycled plastics will emerge. It does not assume leadership for itself, but supports local universities to do so, because of three reasons:

- Universities can be an appropriate "nucleus" for accumulating knowledge on the integrated solid waste management;
- They have more capacity to combine inputs from diverse disciplines;
- They have access to public funds and continuity is guaranteed.

Copesul's leadership believes that a cycle of projects can remove the barriers among the organizations involved.

Universities
The academic life in Brazil, including Porto Alegre, suffers from a lack of commitment. Without question, this is a consequence of the way that research programs have evolved. It is often unclear what the impacts are of research. Cooperation between disciplines hardly ever happens. The existing culture and perceptions must be changed. For all these reasons, GIGA is very important for UFRGS. It offers an opportunity to acquire knowledge and combine knowledge across various disciplines, with clear expectations regarding the impacts of the research within GIGA.

(*) The stakeholder profiles were based on interviews with DMLU, Copesul, and UFRGS, that were conducted two weeks before the first workshop.

2. The First Workshop

The Results of Steps 1 and 2

In step 1, the problem of municipal solid waste was quickly brought to life with a presentation of tendencies and the state-of-the-art in the management of municipal solid waste. Then, in step 2 participants agreed on the objective: "To obtain a model for the integrated management of MSW that minimizes environmental damages and maximizes environmental, social and economic benefits, or in other words, to develop a model that balances the environmental, social and economic objectives within a vision of sustainable development." A brainstorm followed, with participants suggesting keywords to express this objective distinguishing three sub-goals marked: Environmental, Social and Economic.

Step 3: The System Elements

In step 3, the participants advanced to a system representation concerning the problem of MSW, first of all by defining the elements of the system.

Components and characteristics
The participants reached consensus concerning: which elements in the system are most relevant? First, "components" were defined to outline the content of the model. Then, in order to be more specific, "characteristics" were defined for each component. For example, the component Recovery of discarded material can refer to the Quality of recovery of that material, or to the Volume of the recuperated material.

Table 1 Components and characteristics defined by the participants

Components	**Characteristics**
Recovery	Quality Volume
Quality of Life	Quality of Life
Legislation	Scope
Technology	Applicability
Environmental Education	Scope Frequency
Market	Value Volume
Products	Reintegratability
Costs	Costs
Residues	Quantity Complexity
Energy	Consumption Cost Supply
Environment - Air, Soil, Water	Quality Quantity
Industry	Recycled Prime Materials Rejects
State	Fiscalization Promotion
Civil Society	Participation Promotion
Institutions for Learning	Diffusion Training
Worker	Qualification Number

Step 4: The Interactions Between the Elements

In step 4, the participants added another ingredient to the system representation of the problem: the interactions between the elements.

<u>Interactions between components</u>
First, the participants established consensus about the interactions between components; again, to outline the content of the model. For example, Figure 33 shows that the component Recovery (Br. Recuperação) was considered to have a certain influence on the component Environment (Br. Ambiente). How this influence worked out the participants did not know yet, but they did know that it existed.

	Recuperação	Qualidade de Vida	Legislação	Tecnologia	Educação Ambiental	Mercado	Produtos	Custos	Resíduos	Energia	Ambiente	Indústria	Estado	Sociedade Civil	Inst. Ensino	Trabalhador
Recuperação				X		X	X				X	X				X
Qualidade de Vida									X	X				X		
Legislação					X	X	X		X	X	X	X		X		
Tecnologia	X					X	X		X	X	X					
Educação Ambiental	X								X	X	X			X		
Mercado																X
Produtos	X					X			X	X	X					
Custos																
Resíduos	X									X	X					X
Energia		X								X		X				
Ambiente											X					
Indústria							X			X	X					
Estado	X		X											X		
Sociedade Civil		X		X						X	X				X	
Inst. Ensino				X	X									X		X
Trabalhador	X					X					X					

read: the horizontal component has a certain influence on the vertical component

Figure 33 The interactions between components that were indicated by the participants

<u>Interactions between characteristics</u>
Then, in order to be more specific, interactions between characteristics were defined. Two examples of interactions between characteristics are:

- the Qualification of the Worker has a direct influence on the Quality of Recovery;
- the Volume of Recovery has a direct influence on the Quality of the Environment.

Each interaction has a direction (positive or negative) and intensity, see Table 2 and Figure 35

Table 2 Notation of the possible interactions between characteristics

Influence of characteristic A on characteristic B:		
+++		if A increases, B increases conformly(*)
++		if A increases, B increases moderately
+		if A increases, B increases weakly
0		no direct influence
-		if A increases, B increases weakly
- -		if A increases, B increases moderately
- - -		if A increases, B increases conformly(*)

(*) The maximum intensity corresponds to a conform increase or a decrease; the analysis does not permit amplifications.

<u>Visualization of interactions between characteristics</u>
Using the same colors as in Table 2, part of the information in Figure 34 can be visualized as shown in Figure 35. This diagram shows the interactions between the characteristic Quality of the component Recovery and the other characteristics.

	REC Qualidade	REC Volume	QUA Qualidade de Vi	LEG Abrangência	TEC Aplicabilidade	EDU Abrangência	EDU Frequência	MER Valor	MER Volume	PRO Reintegrabilidac	CUS Custos	RES Complexidade	RES Quantidade	ENE Consumo	ENE Custo	ENE Oferta	AMB Qualidade	AMB Quantidade	IND Matéria Prima R	IND Rejeitos	EST Fiscalização	EST Promoção	SOC Participação	SOC Promoção	INS Difusão	INS Formação	TRA Número	TRA Qualificação
REC Qualidade					++			+		++									+++								+	
REC Volume					++			-									+++	+++	+++								+	
QUA Qualidade de Vid													++	++									++	++				
LEG Abrangência						++	++	+	+	+++		--	--	-	+	-	++		+++	---			++	++				
TEC Aplicabilidade	+++	+++						+++	++	+++		--	---	-	-	+	++	++										
EDU Abrangência	+++	+++										--	--	-			+						++	++				
EDU Frequência	++	++										-	-	-			+						++	++				
MER Valor																											++	++
MER Volume																											++	
PRO Reintegrabilidade	++	+++						++	++				---	--	--		+	+										
CUS Custos																												
RES Complexidade	--	---												++			--	--										
RES Quantidade		++												+			--	--									++	
ENE Consumo			+												-													
ENE Custo			--											---						-								
ENE Oferta			++											+++	---													
AMB Qualidade																												
AMB Quantidade																	+											
IND Matéria Prima Re										++							++	++										
IND Rejeitos														++	++		--	--										
EST Fiscalização	++	++																					++	++				
EST Promoção	++	++		++																			++	++				
SOC Participação			++		+									-	-	+	+	+							++	++		
SOC Promoção			++		+									-	-	+	+	+							+++	+++		
INS Difusão					++	++	++																+	+			++	++
INS Formação						++	++																+	+			++	++
TRA Número		+++						+	++																			
TRA Qualificação	+++	+++						+									++											

Figure 34 The interactions between characteristics, indicated by the participants

Visualization of interactions between characteristics

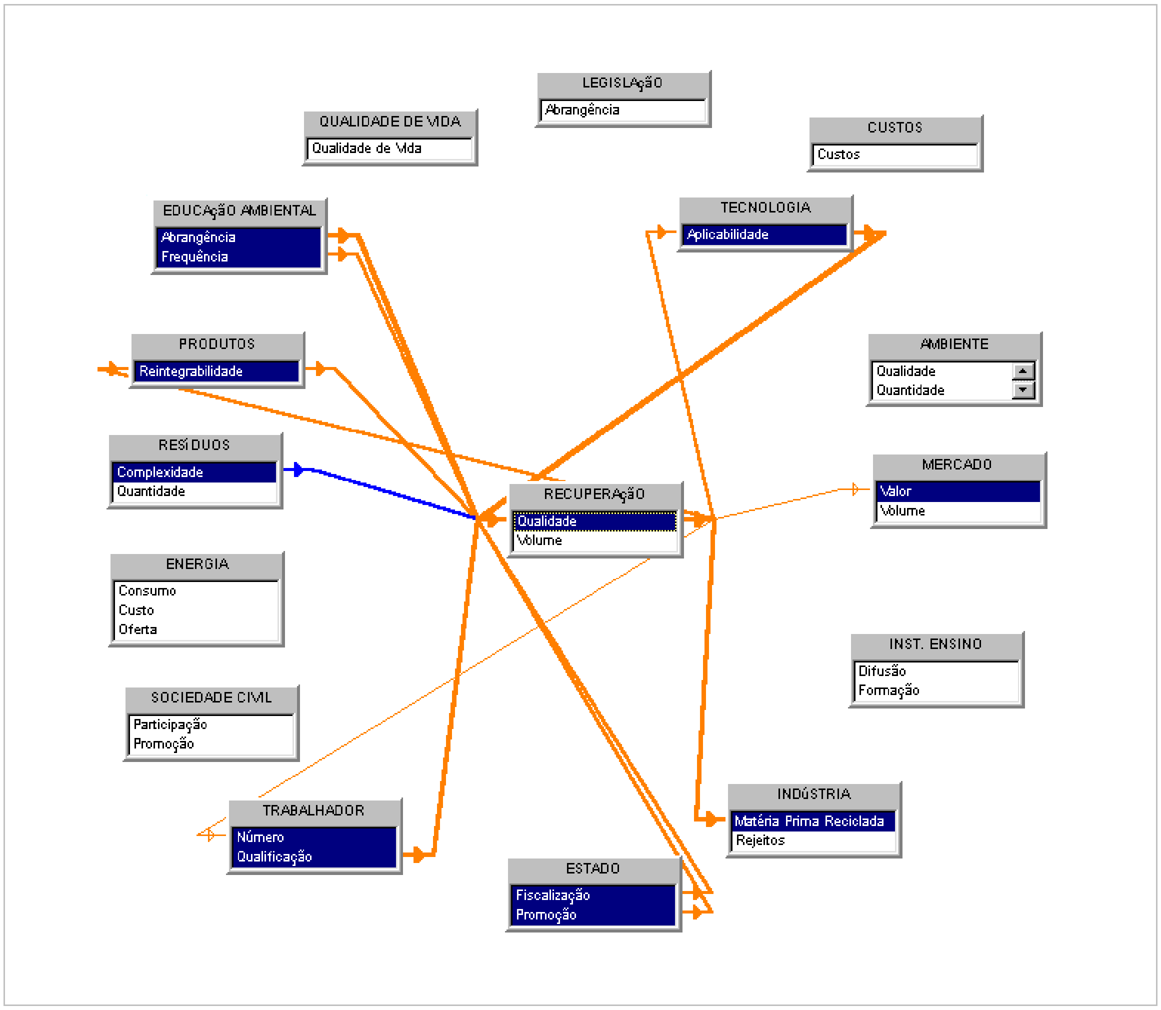


Figure 35 The interactions that correspond to the characteristic Quality (Br. Qualidade) of the component Recovery (Br. Recuperação)

3. The Intermediary Steps

Steps 5 and 6: Analysis and Evaluation

Between the two workshops, additional data were collected from the participants through e-mail. These contributions were necessary to complete step 5: "analyze and evaluate the changes as a result of strategies".

Propagation of changes
In this step, participants considered how changes propagated through the system that was represented by the model. This was comparable to asking: if I change something in this part of the system, what happens in other parts of the system? Such analysis served two goals:

- to consolidate the model. The system representation would not be complete if one did not have a way of knowing how system interventions could have an impact on system performance.
- to place ends vs. means. To be able to learn about the policy consequences, participants had to define what kinds of system interventions were possible (in terms of strategies) and how system performance was measured (in terms of objectives and criteria).

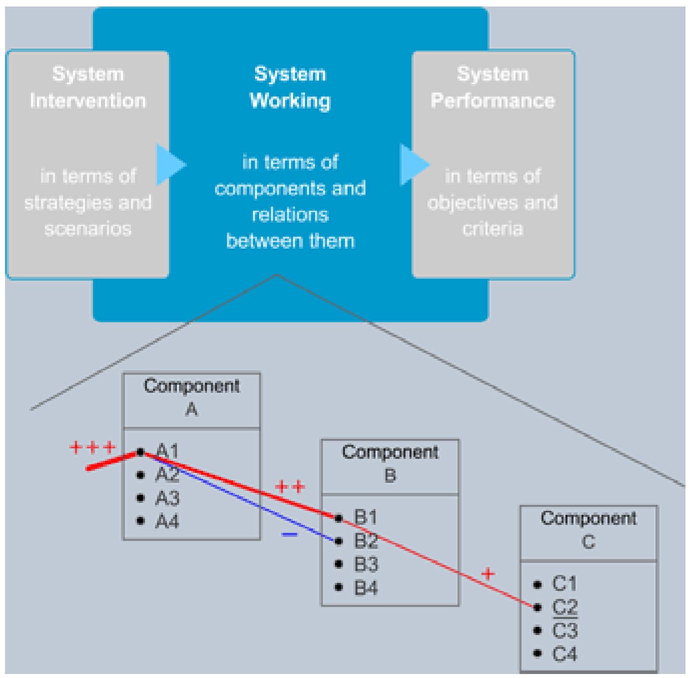


Figure 36 The rapid assessment model places ends vis-à-vis means

System interventions
System interventions were defined in two stages.

1) The most interesting system interventions - considered to be feasible - were defined as "measures". For example, one measure was defined as "a moderate increase (++) of Training" (a characteristic of Institutions for Learning). After that, coherent sets of measures were formed. These sets were defined either as "strategies" or "scenarios"; the former were the interventions considered to be under their control, the latter not. For example, the strategy Training and Diffusion was defined as a coherent set of two measures: "a moderate increase (++) of Training (Institutions for Learning)" and "a moderate increase (++) of Training (Institutions for Learning)".

2) Participants then defined how system performance was measured. First, interesting performance indicators were identified and defined as "criteria". Then, criteria were grouped according to the three sub-goals Environmental, Social and Economic.

Definition of measures and strategies
The intermediary step served to have participants define the measures and strategies. The participants were able to complete this step individually. The basic question asked to them was: what is the best way to influence the criteria[22].

There was an important difference between this activity and the previous steps: whereas in the (first) workshop it was crucial that consensus was reached among the participants, this step called for the individual perceptions and the creativity of the participants.

Selection of criteria
The participants indicated which characteristics could be used as criteria for the evaluation of strategies. They reached consensus on a set of thirteen criteria. See Table 3.

Table 3 The criteria grouped according to three sub-goals

Criteria	
Environmental	Quality of Recovery Scope of Legislation Scope of Environmental Education Complexity of Residuals Quantity of Residuals Product Reintegratebility
Social	Quality of Life Promotion of Civil Society
Economic	Energy Consumption Industry Rejects Promotion of State Number of Workers Applicability of Technology

[22] The RAP software was helpful here, because it allowed to visually explore how changes propagated through the system (which was difficult to do mentally, especially with propagations of large orders).

Strategies

Table 4 The strategies that were most cited by the participants

Strategies
1. Training and Diffusion Measures: • a moderate increase (++) of Training (Institutions for Learning) • a moderate increase (++) of Diffusion (Institutions for Learning)
2. Environmental Education Measures: • a moderate increase (++) of Scope (Environmental Education) • a strong increase (+++) of Frequency (Environmental Education)
3. Efficiency of the Recycler Measures: • a moderate increase (++) of Qualification (Worker)
4. Commitment of Society Measures: • a strong increase (+++) of Participation (Civil Society)
5. Legislation Development Measures: • a moderate increase (++) of Scope (Legislation)

Analysis and evaluation of strategies
The participants also estimated the changes that would result from the strategies that they had defined. Because of the wide variety in the estimates of the participants, consensus was established in the second workshop concerning the expected changes that result from the five strategies in Table 4. These results are shown in Figure 39.

4. The Second Workshop

The objective of the second workshop was "to extend the system model of the first workshop with elements related to the network of actors that are mutually responsible for the management of the system". First, the participants indicated eight actors of the network that they considered most important to include in the analysis. Then, in order to integrate their knowledge about the network in the system model, the participants established relations between actors and strategies and between actors and criteria, in interactive manner.

Actors
The participants indicated eight actors of the network that they considered most important to include in the analysis:

Table 5 The actors indicated by the participants

Actors
Civil Society
State
Municipality
Institutions for Learning
Industry
Distribution & Commercialization
Recycling Organizations
Recyclers

Relations between actors and strategies
In the next step, the participants established relations between actors and strategies and between actors and criteria, in interactive manner. The relations were expressed using the concept of "proximity": the "distance" between an actor and a strategy or a criterion tells something about the relation between the two. In this activity, proximity and distance were used as relative concepts: relative to the other strategies, to the other criteria, to the other actors. The two graphical representations Figure 37 and Figure 38 facilitated the participants in establishing consensus.

<u>Relations between actors and strategies</u>
First, the participants indicated the relations between actors and strategies. The question was: what is the level of control that the actor has over that strategy? If an actor has a relatively high level of control over a strategy, the distance is small.

Figure 37 shows that the actors with the highest level of control over strategy Training and Diffusion are: Institutions for Learning, State and Recycling Organizations. The lowest levels of control have the actors Industry, Distribution & Commercialization and Recyclers.

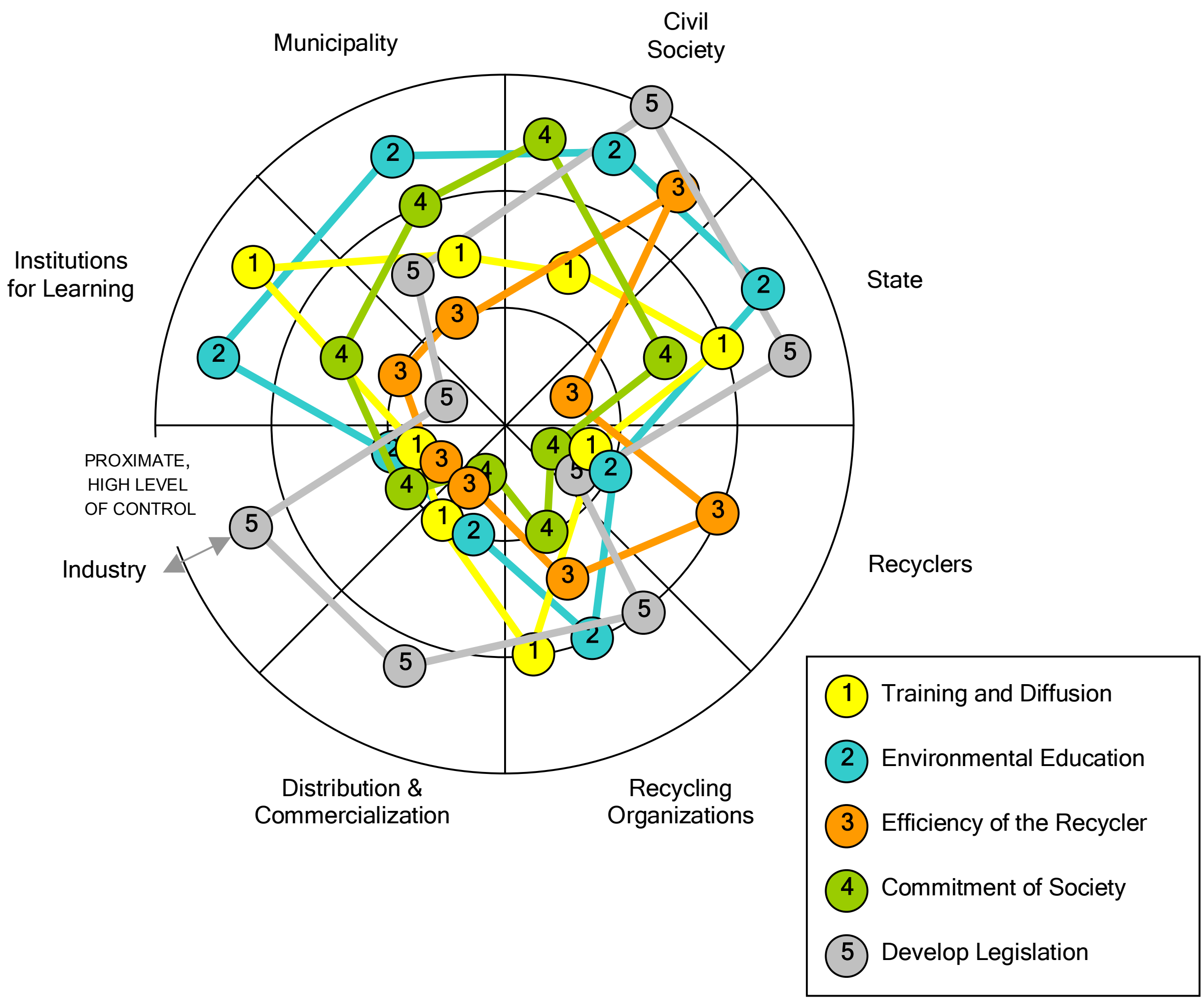


Figure 37 Relations between actors and strategies; their proximity reflects the actor's level of control over a strategy

Relations between actors and criteria
The participants also indicated the relations between the actors and the criteria. The question was: what is the importance of that criterion for the actor? If a criterion has relatively high importance for the actor, the distance is small. To advance more rapidly, the thirteen criteria were considered as in Table 3; grouped according to the sub-goals Environmental, Social and Economical.

Figure 38 shows that the actors that attribute the highest importance to the criteria in the Environmental group are Civil Society and Municipality. The actors Recyclers and Distribution & Commercialization attribute the least importance.

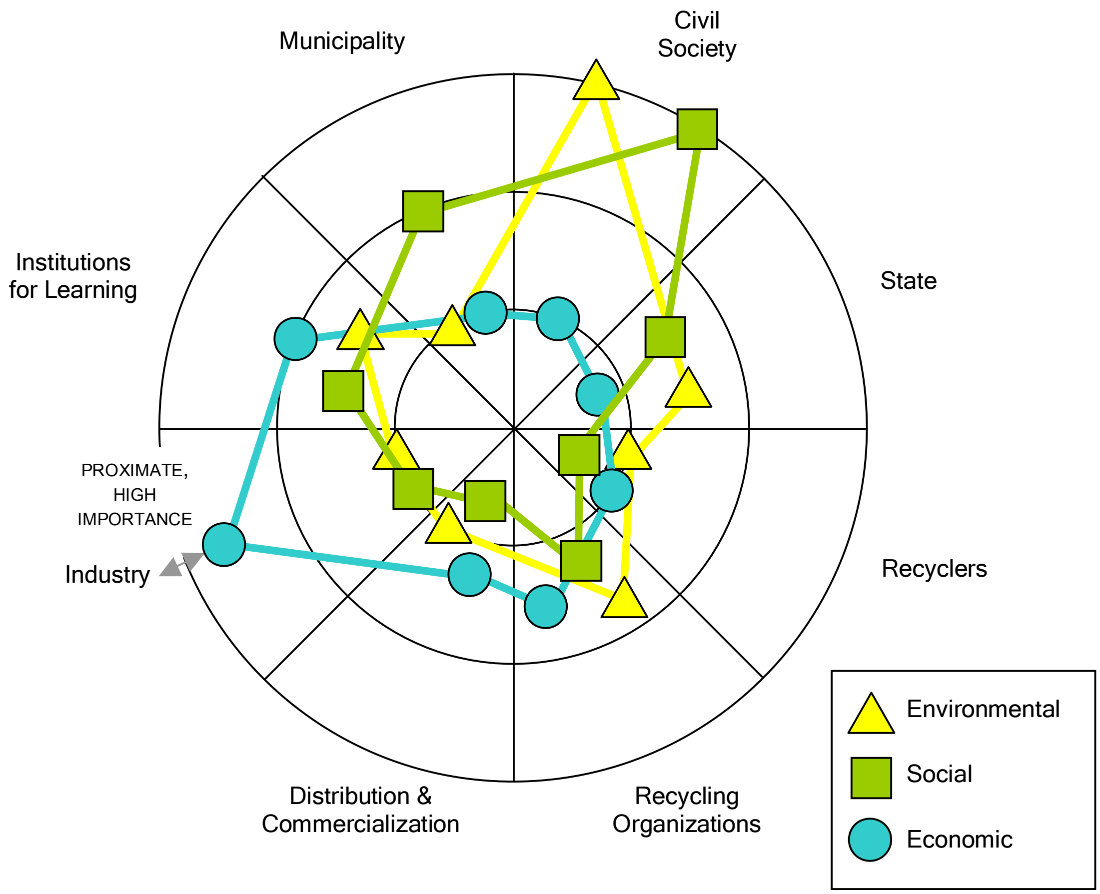


Figure 38 Relations between actors and criteria; their proximity reflects the importance of the group of criteria for the actor

(re)Analyse and (re)evaluate strategies
The data contributed before the second workshop contained estimates by the participants concerning the changes that would result from the strategies. In addition, the software was used to estimate the changes in preparation of the workshop. Because of the wide variety in the estimates, the second workshop included an activity in which the participants established consensus about the changes that resulted from the five strategies in Figure 39 shows the results of this activity.

	Qualidade de Recuperação	Abrangência de Legislação	Abrangência de Educação Ambiental	Consumo de Energia	Rejeitos de Indústria	Qualidade de Vida	Promoção de Estado	Promoção de Sociedade Civil	Número de Trabalhadores	Aplicabilidade de Tecnologia	Complexidade de Resíduos	Quantidade de Resíduos	Reintegrabilidade de Produtos
1. Formação e Difusão	++ .. +++	+	+++	-	- -			++		+	-	- - .. 0	+
2. Educação Ambiental	+++		++ .. +++	++	- .. 0	++		++		0 .. +	-	- -	+
3. Eficiência do Reciclador	+++			- -					- .. +	++			++
4. Comprometer a Sociedade	+		+	-		+		+				- -	++
5. Desenvolver a Legislação	0 .. +	+	++	-	- -	+	+			+	- -	- -	++

Figure 39 The changes resulting from the strategies, estimated by the participants

5. The Analysis

The analysis is comprised of three parts:

1) Representation of the system: an integrated model?
   In the first part of the analysis it is verified whether the data are complete and consistent. What knowledge is still lacking?

2) Strategies: where are the synergies?
   We concentrate our attention on the estimates of the changes resulting of the five strategies by the participants (in Table 4) with the question: which is the best way to influence our criteria? Our interest is particularly in sets of strategies; we try to locate the synergies between the five strategies.

3) What are the arenas?
   The data of the second workshop (concerning the actors) show differences between actors with respect to the levels of control over strategies and the levels of importance of criteria. Consequently, we can think of the co-existence of multiple "arenas". The network (GIGA) can evolve as a "platform" where it is possible to discuss contradictions that emerge from the arenas. Such platform would also allow competition between divergent perspectives and alternative solutions. We try to identify the arenas.

Analysis 1: An Integrated Model?

The representation of the system built by the participants contains 16 components and 28 characteristics (captured in Table 1 and Figure 34).

Observations based on inspection of the model:

- The model describes tendencies that promote the recovery of the residues and potential synergies.
- The model does not describe the costs (environmental, economic) involved, nor the function of markets, nor the alternatives for treatment and disposal.
- There is a tendency to perceive the challenge of "developing a model of integrated management of MSW" as the challenge to "plan a system of improved recovery". The second perception is not holistic and led participants to leave out environmental and economic costs.

Conclusion: The knowledge that is still lacking:

- environmental costs;
- economic costs;
- function of markets;
- alternatives for treatment and disposal.

Observation based on the propagation of some changes ("measures") using the RAP software:

- Measures are mostly potentially synergetic, with exception of the tensions that exist with respect to the increase of well being (higher volume of residues, higher use of energy) and an increase in efficiency (smaller number of workers).
- The model confirms in part the hypothesis of GIGA: the diffusion of knowledge is essential; the influence of an increase in training is smaller.
- Legislation is the measure with the biggest impact.
- More participation of civil society is highly desirable; however the increase should be strong to produce an impact.
- The objective "less complexity of residues" is difficult to achieve.

Conclusion: Propagation of some changes ("measures") using the RAP software confirms most of the existing institutions of the participants about the behaviour of the system. When we include the knowledge that still is lacking (economic costs etc.) this type of propagation could result in counterintuitive results.

Analysis 2: Where are the Synergies?

Figure 40 shows a scorecard for evaluation of strategies. The scorecard presents the information of Figure 39 in a different way.

Observations based on inspection of the scorecard:

- The "institutional" strategies Training and Diffusion, Environmental Education and Legislation Development have the biggest impacts and affect the criteria of all sub-goals.
- The impact of the "technical" strategy Efficiency of the Recycler depends on the importance of the environmental criteria Quality of Recovery, Product Reintegratability and economic criteria Energy Consumption, Number of Workers and Applicability of Technology.
- The impact of the "social" strategy Commitment of Society depends on the importance of the environmental criteria Quality of Recovery, Scope of Environmental Education, Quantity of Residues, Product Reintegratability and social criteria Quality of Life and Promotion of Civil Society.

Conclusion: The best way to influence the criteria is an approach that is predominantly institutional (training, education, legislation) with synergies in technical and social programs. In particular:

- increase the quality of recovery (training, education, technical);
- decrease the quantity of residues (training, education, legislation, social);
- increase the product reintegratability (legislation, technical, social);

SCORECARD

1. Training and Diffusion
2. Environmental Education
3. Efficiency of the Recycler
4. Commitment of Society
5. Legislation Development

	- - -	- -	-	0	+	++	+++
Environmental							
Quality of Recovery				5	4, 5	1	1, 2, 3
Scope of Legislation					1, 5		
Scope of Environmental Education					4	2, 5	1, 2
Complexity of Residues		5	1, 2				
Quantity of Residues		1, 2, 4, 5	1	1			
Product Reintegratability					1, 2	3, 4, 5	
Social							
Quality of Life					4, 5	2	
Promotion of Civil Society					4	1, 2	
Economic							
Energy Consumption		3	1, 4, 5			2	
Industry Rejects		1, 5	2	2			
Promotion of State					5		
Number of Workers			3	3	3		
Applicability of Technology				2	1, 2, 5	3	

Figure 40 The changes as result of strategies, as indicated by the participants (potential synergies are marked with boxes)

Analysis 3: What are the Arenas?

Figure 37 and Figure 38 show differences between actor with respect to the levels of control over the strategies and the levels of importance of criteria. Consequently, we can think of the co-existence of multiple "arenas". For each strategy, a representation of the corresponding arena is produced, as shown in Figure 41:

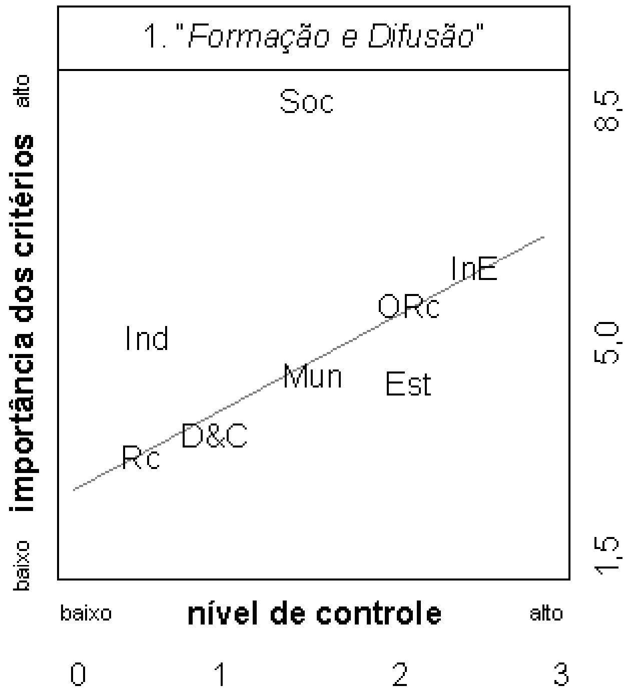


Figure 41 The arena for the strategy Training and Diffusion

how the coordinates of the actors are derived:

level of control:	the information in Figure 37
importance of criteria:	calculated(*) using the information in Figure 38 and Figure 39

(*) We already know the impacts of a strategy on the criteria (in Figure 39) and the levels of importance of the criteria for each actor (in Figure 38). For each actor the importance of the criteria is calculated considering the impacts of the strategy.

Figure 41 shows that the impacts of the strategy Training and Diffusion are highly important for the actor Civil Society however it has little control over that strategy. For the other actors, the level of control appears to be matching more or less the importance of criteria (the match is indicated with a sloped line).

The study of the representations in Figure 42 focuses on the disproportions in control over strategies considering differences between the actors. In the case of strategy Training and Diffusion, an increase in control over that strategy may be desirable.

We can also observe differences between the arenas. The arena that corresponds to the strategy Efficiency of the Recycler contains more disproportions in control than the others. In this case, a change of the involvement of the actors ("restructuring" the arena) and an increased level of coordination may be necessary for implementation of the strategy.

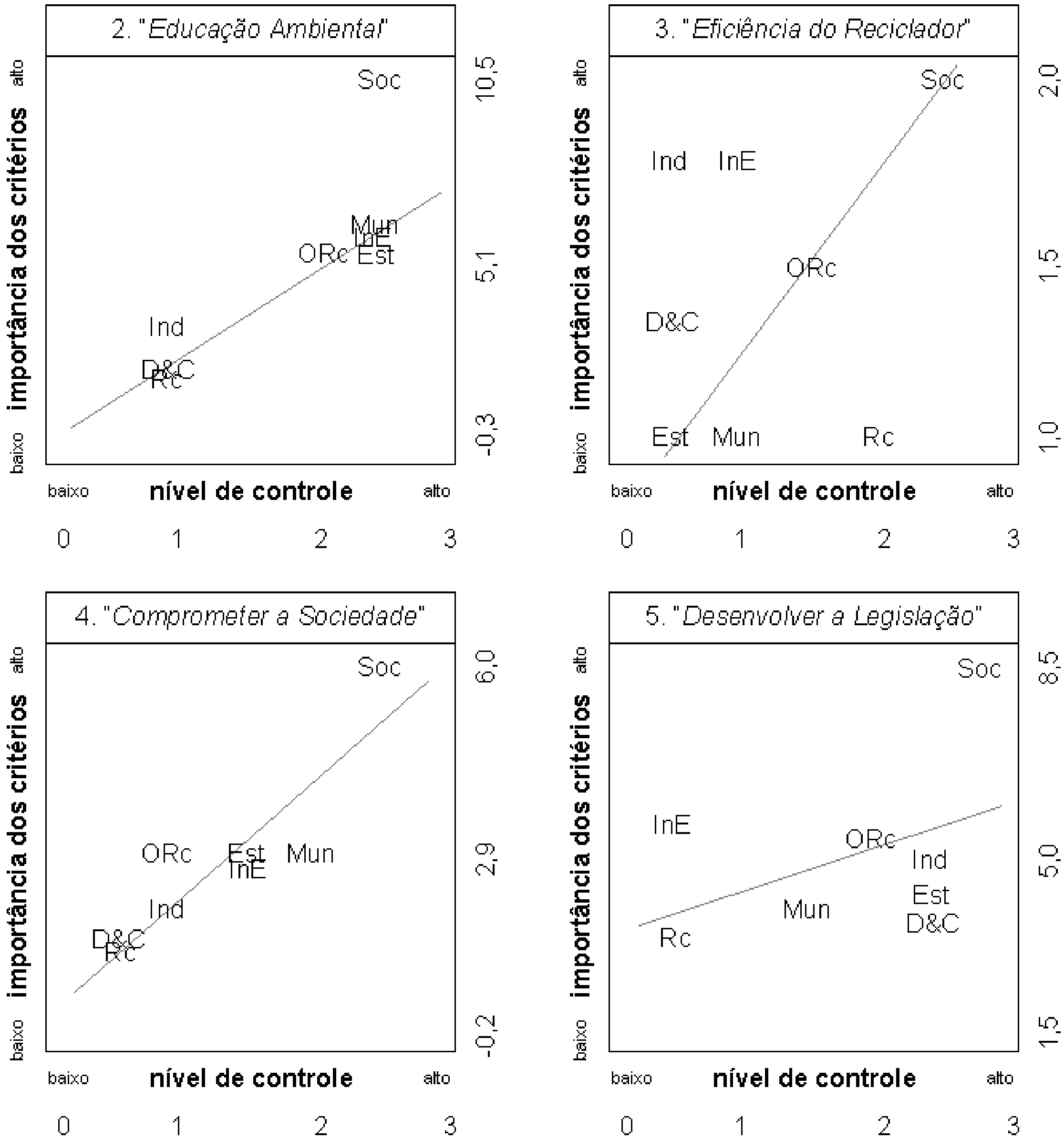


Figure 42 The arenas for four strategies: Environmental Education, Efficiency of the Recycling, Commitment Society and Legislation Development

6. Reflections on the Workshops Dynamics

The previous sections addressed primarily the knowledge contained in models. In the conclusion of this Chapter this thesis author takes a different look at what has been covered in the previous sections, with focus on "process" instead of "content".

The Workshops: About the "Process"

An important condition in Brazil is the already mentioned lack of commitment. It was very difficult to obtain commitment for participation in 2 x ½ + 1 x ½ days from participants for the workshops. This was compensated for by an uncomplicated, flexible attitude during the workshops that was especially appreciated when electrical power suddenly broke down. Brazilians are primarily focused on the social aspect of these events; the "content" is secondary and at times disappears entirely into the background. Consequently, there were hardly ever profound discussions about content in which contradictions or tensions could have surfaced. From this background it can be explained why the workshop results tended to confirm intuition, or in other words, why surprising counterintuitive results were not uncovered. An advantage was that we were able to iterate over all steps in the limited time that was available.

The software only played a minor role in keeping a digital record of the results. Participants were not interested in the insights that were produced using the analytical features of the software. This, however, posed no problem for the logistics of the workshops. One lesson learned was that this kind of workshops can be especially effective in Brazil when they are organized as a "social event", i.e. working with a minimal set of abstracting tools like software or modeling concepts. During the preparation the consultants were able to delete a number of concepts from the rapid assessment vocabulary, because they were unnecessarily confusing or even redundant! They worked instead with markers on wallpaper and paper that were found to be very effective. In retrospect, the event might have been more successful if it had been designed with a more playful character.

It is too easy to think that Brazilians pay too much attention to the social aspect and neglect the "content" (neither does the opposite happen in countries like the Netherlands). The Brazilian way of working toward solutions is to repeatedly explore the other and seek for openings within the relations that emerge. This can lead to situations that solutions are found that are logical from the social point of view, but as regards "content" seem to have come from nowhere (this is what Brazilians call a "jeitinho").

<u>Socio-cultural context</u>
The workshops gave evidence of the importance of the socio-cultural context for the design of decision-support for the learning action network. For a given socio-cultural context, the consultants needed to know what determines the effectiveness of communication of knowledge.

This case study was motivated by the anticipation that one of those determinants is how the network deals with contradictions and tensions that emerge as a consequence of parallel, competing voices, and that are inherent to a learning-action network. See figure Figure 43.

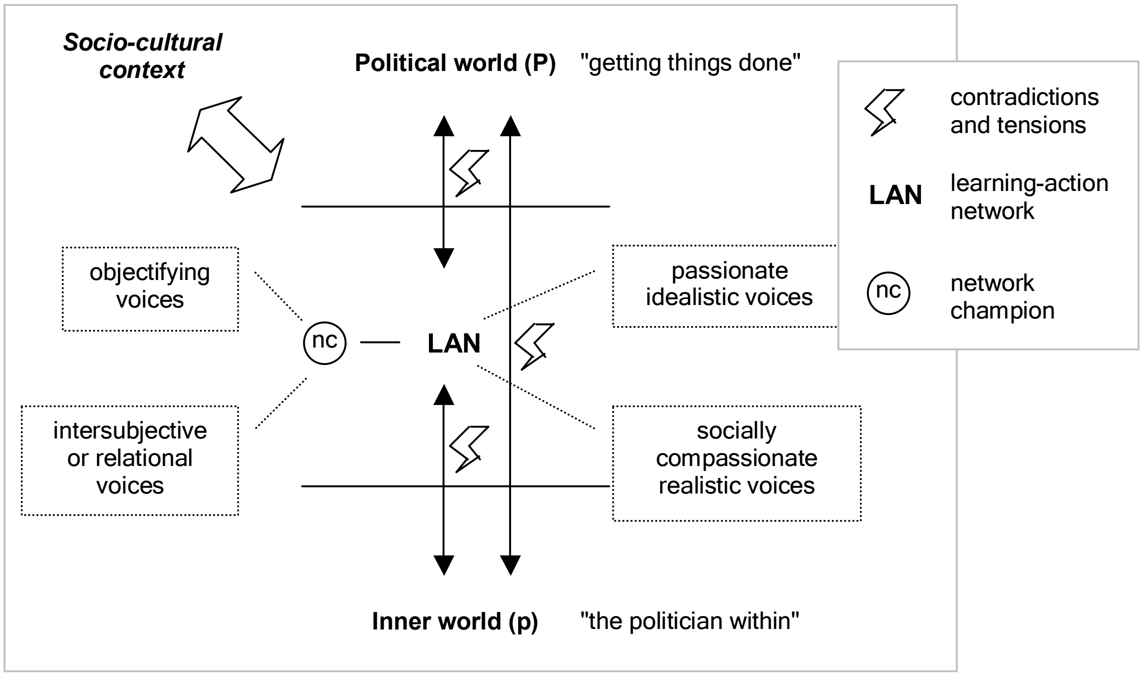


Figure 43 Support for the learning-action network and the importance of the socio-cultural context

APPENDIX B PART 6, PORTO ALEGRE CASE STUDY

FROM RAP+ TO AGENT-BASED SIMULATION

1. Introduction

Can RAP+ and agent-based simulation be used as complementary approaches? This exercise covered in this section provides an answer to this question. Further, the exercise illustrates the potential use of RAP+ modeling as a "backbone" to support the Experimental Design Framework.

To see how this could work, consider Table 6. The table shows that there is a match between RAP+ modeling and an agent-based simulation.

Table 6 Comparison between RAP+ modeling and agent-based simulation

RAP+ modeling	**Agent-based simulation**
Strategies and criteria	Perspectives
System components	Agents and medium
Interactions between components	Behavioural rules

2. The Exercise

In the exercise it is examined whether the RAP+ model from the Porto Alegre case study could potentially be of use in steps 2 and 3 of the Experimental Design Framework.

Table 7 This exercise and the Experimental Design Framework

This Exercise	**The Experimental Design Framework**
	Step 1. Select building blocks
From strategies and criteria to perspectives	Step 2. Produce perspectives
From system components to agents and medium	Step 3. Define models
From interactions between components to behavioural rules	
	Step 4. Conduct experiments
	Step 5. Produce scenarios
	Step 6. Evaluate building blocks

Step 2 is addressed in particular:
Can perspectives be crystallized out of the criteria and strategies in the RAP+ model?

Throughout this exercise, the production of alternative perspectives is performed using the RAP+ model in and other resources. See Table 8 and Figure 44.

Table 8 The use of RAP+ resources in the development of perspectives

Perspective	Resources
Perspective #1	Scorecard with results of the evaluation of strategies
Perspective #2	Facilities in RAP+ for tracking the propagation of changes
Perspective #3	Actor perspective (arenas)

The reader is reminded that the perspectives:

- are based on the a set of building blocks;
- are written using narrative, indicating what scripts are valid;
- tell different stories about possibly different phenomena, the fundamental processes behind them and expectations about the dynamics that can be observed in an experiment.

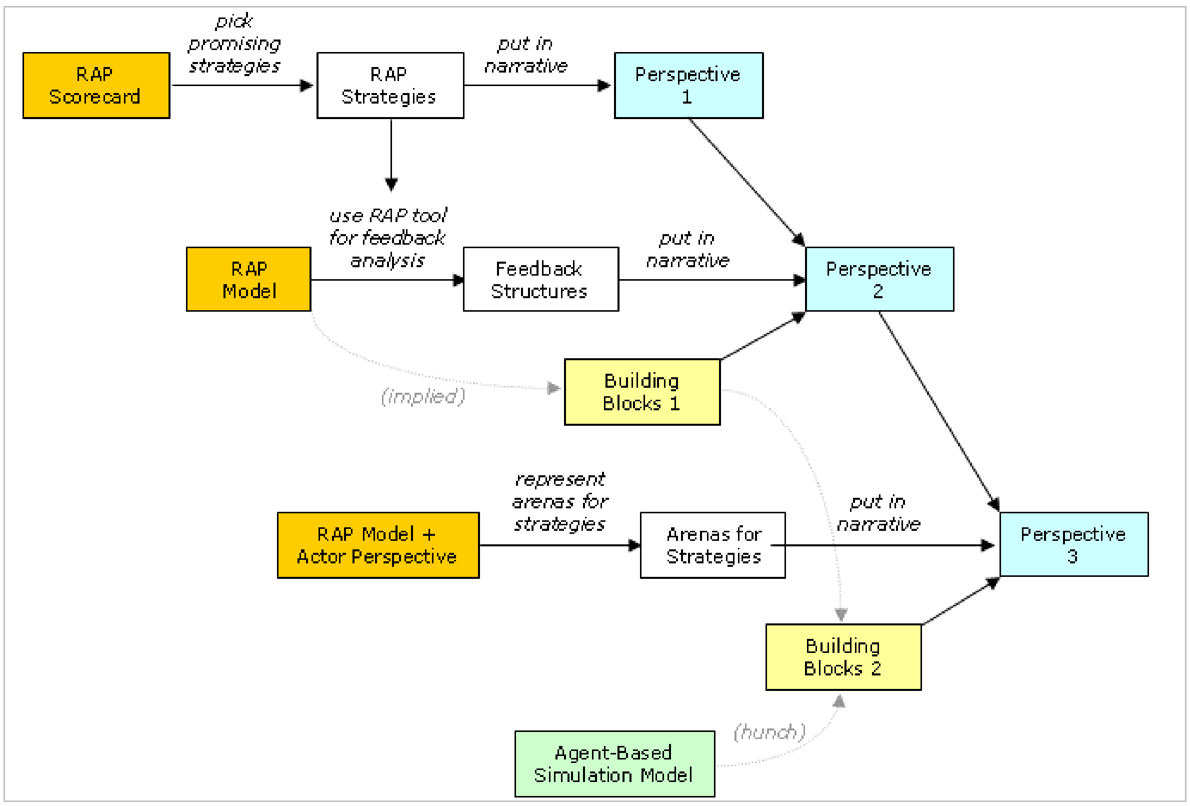


Figure 44 The use of the RAP+ model and other resources in the development of perspectives

2. Perspective #1, Based on the Scorecard

Strategies
A good start is to look at the strategies that emerged from the workshops. The analysis of strategies and their synergies, based on the scorecard (Figure 40) showed that there were three promising approaches:

- Increase the quality of recovery. An approach that seeks implementation of measures that are designed to increase the quality of recovery, following a predominantly institutional approach (strategies: Training and Diffusion, Environmental Education) with synergies in technical programs (strategy: Efficiency of Recycler)
- Decrease the quantity of residues. An approach that seeks implementation of measures that are designed to decrease the quantity of residues, following a predominantly institutional approach (strategies: Training and Diffusion, Environmental Education, Legislation) with synergies in social programs (strategy: Commitment of Society)
- Increase product reintegratability. An approach that seeks implementation of procedures that are designed to increase product reintegratability, following a predominantly institutional approach (strategy: Legislation) with synergies in technical (strategy: Efficiency of Recycler) and social programs (strategy: Commitment of Society)

The following elaboration is performed on one perspective only: "to increase the Quality of Recovery".

In the RAP model, this perspective involved three strategies:

- Training and Diffusion;
- Environmental Education;
- Efficiency of Recycler.

The information contained in the scorecard (Table 12.8) is sufficient to produce a narrative version of the perspective.

Perspective #1: Quality of Recovery

based on the RAP scorecard

Measures taken:
Our first perspective on the management of municipal solid waste considered an approach that sought implementation of a set of measures that were designed to improve the quality of recovery. These measures were:

- to have institutions of higher learning offer improved training opportunities and more diffusion of know-how;
- to increase the frequency of environmental education and to broaden its scope;
- other ways to improve the qualification of the worker.

Expected benefits:
The expected benefits of this approach were not limited to an improved quality of recovery, but included:

- Environmental benefits:
  - Less residues;
  - Improved product reintegratability;
- Social benefits:
  - Improved quality of life;
  - Promotion of civil society;
- Economic benefits:
  - Less industry rejects;
  - Less energy consumption;
  - Increased applicability of technology.

3. Perspective #2, Based on the Analysis of Feedback Structures

Feedback structures

Next, we isolated from the rapid assessment model the feedback structures that were responsible for the impacts shown in the scorecard. To identify these feedback structures, we performed additional analyses by taking a close look at the propagation of the impacts of all measures involved, as is illustrated visually, in Figure 45.[23] [24]

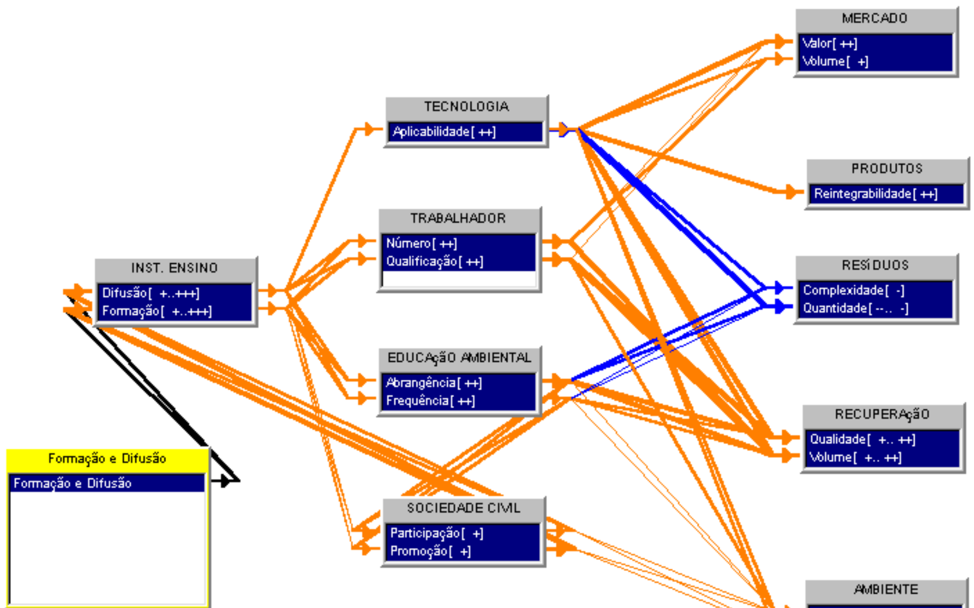


Figure 45 The propagation of impacts of measures involved in improving the quality of recovery through the Training and Diffusion strategy

Interpretation of the figure

It is anticipated that there would be positive impacts due to increased training opportunities and diffusion of know-how on both the quality and the volume of recovery through:

- an increased applicability of technology;
- more and better qualified workers;
- more frequent environmental education with a broader scope.

It was found that the indirect impacts and feedback loops in the figure were of special interest. For example, one positive, self-reinforcing, feedback loop is that "an increase in training and diffusion of know-how has a positive impact on environmental education, which has a positive impact on the participation of civil society, which has a positive impact on the diffusion of know-how."

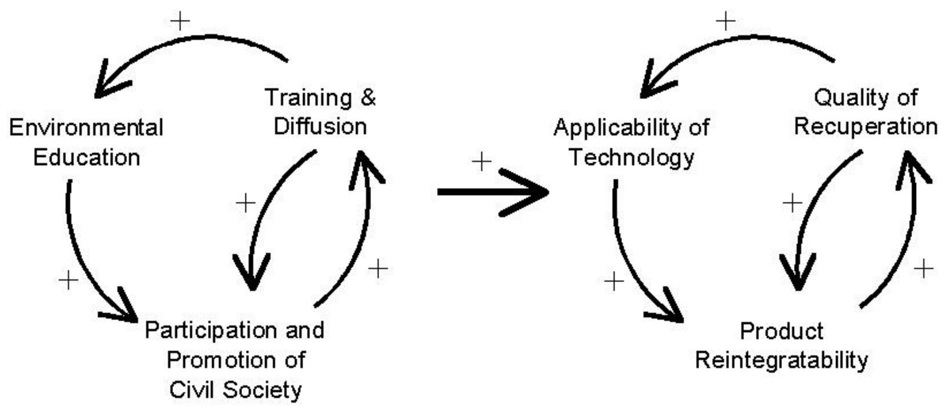
[23] The figure shows impacts different from those in the scorecard for two reasons. First, in the diagrams all measures have maximum intensity [+++], which makes it easier to identify feedback structures. Second, the impacts in the scorecard are not the same as the impacts that can be analytically derived, but instead are estimated impacts that were consolidated in interaction with participants and informed by the analytically derived impacts.

[24] The figure illustrates the propagation of impacts of measures only for the strategy Training and Diffusion. In the analysis two more of such figures were studied; for strategies Environmental Education and Efficiency of Recycler.

The rapid assessment software, used in the workshops, provided a feature to "discover" indirect impacts and feedback loops of greater order: Which loops might be out there to be discovered? Through market value? Through product reintegratability? After analysis with a "larger" picture than Figure 45 it turned out that this was indeed the case:

- more and better qualified workers through increased market value;
- improved quality and volume of recovery through improved product reintegratability.

Figure 12.12 shows the feedback structures in that were isolated from the RAP model.



1. Environmental Education → Quality of Recuperation
2. Training & Diffusion → Qualification of Worker → Quality of Recuperation
3. Training & Diffusion → Product Reintegratability

Figure 46 The feedback structures that could be isolated from the RAP model; they constitute two connected positive (self-reinforcing) feedback loops: a "learning" loop (left) and an "innovation" loop (right)

Selection #1 of Building blocks

It is important to realize, at this point, that the rapid assessment model that was built in the workshop or rather, the modeling language used to build it, already implies a small set of building blocks:

Selection #1 of Building blocks

implied by the rapid assessment model

- From the theme "Integration":
  - Agency for Change(*);
- From the theme "Complexity":
  - Equilibrium & (in)Stability
  - Feedback

(*) In standard RAP, agency of change is always exogenous to the system that is represented.

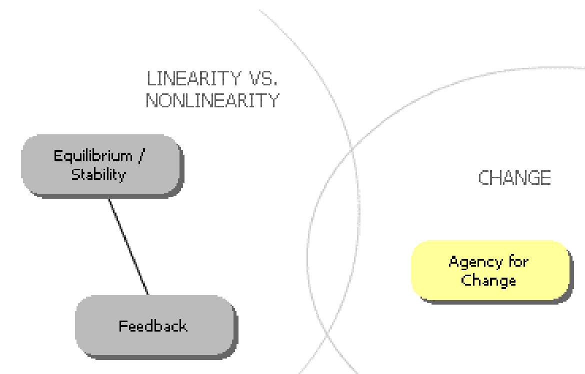


Figure 47 Building blocks implied by the rapid assessment model

Perspective #2

Here then follows the second perspective, using the insights to the dominant feedback structures of relevance in the rapid assessment model.

Perspective #2: Quality of Recovery

based on insight into feedback structures

Measures taken:
Our first perspective on the management of municipal solid waste considered an approach that seeks implementation of a set of measures that were designed to improve the quality of recovery. These measures were:

- to have institutions for learning offer improved training opportunities and more diffusion of know-how;
- to increase the frequency of environmental education and to broaden its scope;
- other ways to improve the qualification of the worker.

Propagation of changes:
Changes as consequences of these measures propel two self-reinforcing feedback loops:

- A "learning" loop with social benefits:
  - Increased participation of civil society;
- An "innovation" loop, that is enforced by the "learning" loop, with environmental and economic benefits:
  - Improved quality of recovery;
  - Improved product reintegratability;
  - Increased applicability of technology.

Expected benefits:
The expected benefits of this approach are not limited to an improved quality of recovery, but also include:

- Environmental benefits:
  - Less residues;
  - Improved product reintegratability;
- Social benefits:
  - Improved quality of life;
  - Promotion of civil society;
- Economic benefits:
  - Less industry rejects;
  - Less energy consumption;
  - Increased applicability of technology.

4. Perspective #3, Based on the Actor Perspective

Arenas

Next, the interactions of actors were addressed, considering the arenas for strategies.

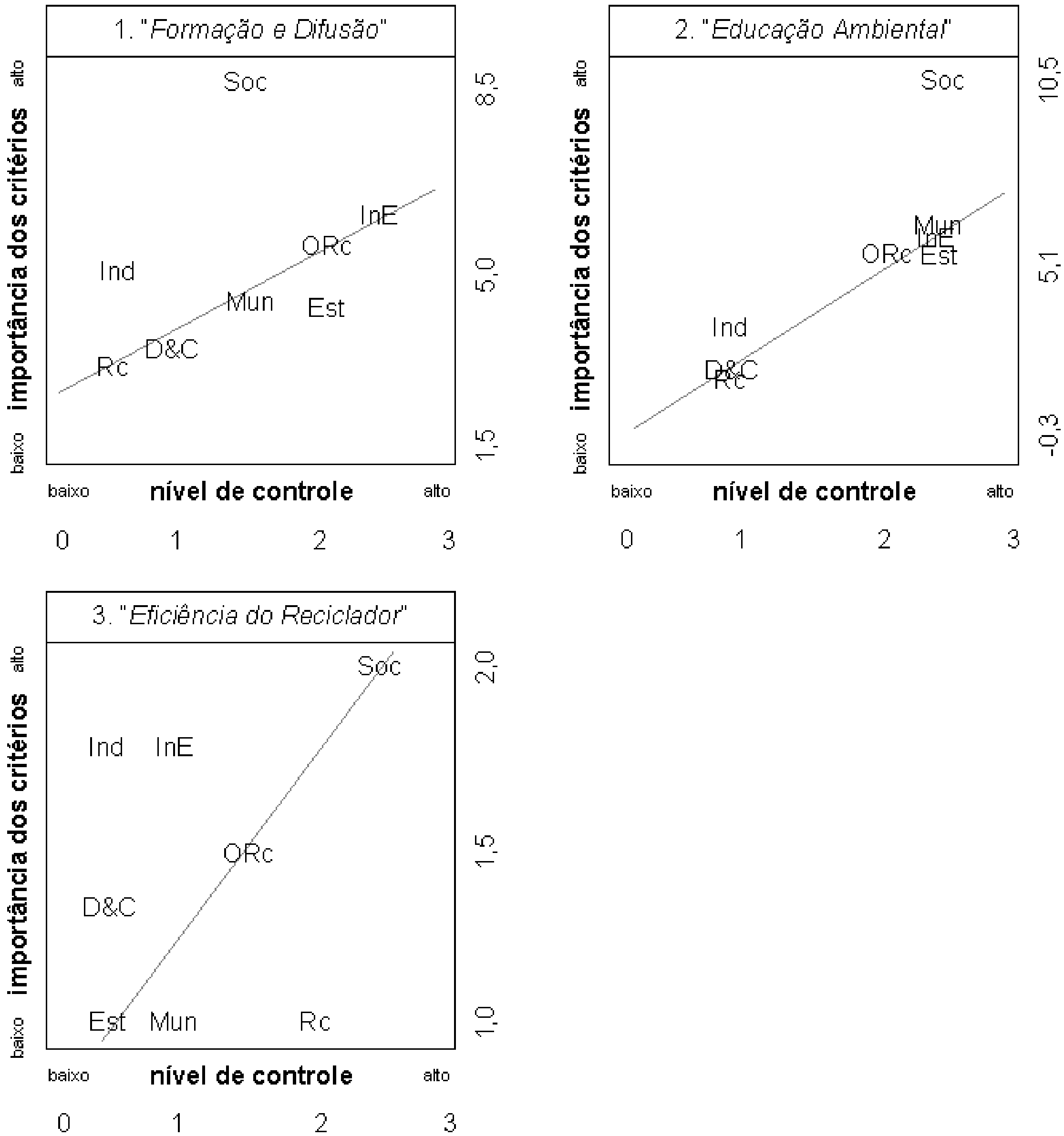


Figure 48 The arenas for three strategies (same as Figure 42)

Quadrants

The arena for Efficiency of Recycler was different from the others, and could provide clues about new reasoning that could be incorporated within the perspective. Figure 49 uses quadrants for a simplified picture of the information in Figure 48.

QUADRANT 1: **low level of control,** **high level of importance** Industry Institutions for Learning	**QUADRANT 2:** **high level of control,** **high level of importance** Civil Society
QUADRANT 3: **low level of control,** **low level of importance** Municipality State Distribution & Commercialization	**QUADRANT 4:** **high level of control,** **low level of importance** Recycler

Figure 49 The arena split into quadrants for strategy Efficiency of Recycler

Analysis of the content of the quadrants
For thinking about the interaction between these actors, the key consideration might be the "valorization" of the worker; a concern that was often expressed by participants during the workshops. Indeed, the reality in South Brazil is that workers in recycling facilities, collectors, etc. are low-schooled and experience little compensation for the work that they do. Consequently, a viable hunch, also uttered by some of the workshop participants, is that a higher salary for these workers could improve the efficiency of the recycler.

Figure 49 can be used to clarify what the hunch implies for groups of actors in each quadrant:

Table 9 The actions suggested by the analysis of the content of the quadrants

Actors	Actions
Civil Society	Raise awareness.
Recycler	Raise the level of importance with incentives.
Industry, Institutions for Learning	Raise the levels of control by involvement.
Municipality, State, Distribution & Commercialization	Involve in a later stage.

Selection #2 of Building Blocks

We elaborated our hunch further by importing additional building blocks into our initial set. The building block Agency for Change was already present in the initial set, however this time the possibility is considered that agency for change is endogenous to the system that is represented.

Selection #2 of Building blocks

expressing a hunch with regard to the valorization of workers

- New building blocks from the theme "Integration":
  - Individual Learning
  - Thought & Feeling Structures

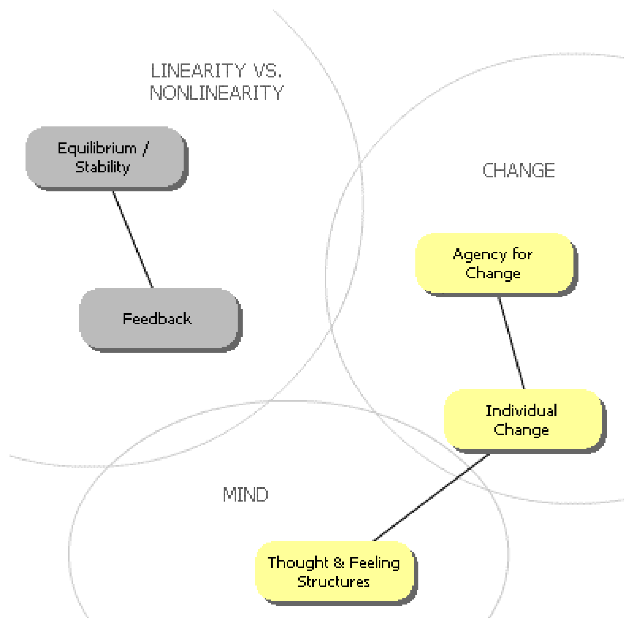


Figure 50 Building blocks that support the hunch about valorization of the worker

Culture
A higher valorization of the worker is perhaps not so much a consequence of dissemination of knowledge as it is a consequence of dissemination of culture. In the interviews before the workshops with members of the GIGA network, cultural change was frequently mentioned as being a critical factor for any change. Of interest here is an agent-based simulation model on "disseminating culture" developed by Robert Axelrod.

Disseminating Culture:

a model by Robert Axelrod

The question that was answered by Axelrod is: "If people tend to become more alike in their beliefs, attitudes and behaviour when they interact, why do not all such differences eventually disappear?" In short, his answer is "local convergence and global polarization"; people become more similar as they interact, but that same mechanism, called "social influence", explains why the tendency to converge stops before it reaches completion.

The interest in Axelrod's answer is demonstrated by an agent-based simulation model that is characterized by his unique approach of modeling social influence (i.e. the way people tend to change each other in the very process of interaction). Further, what is remarkable about the model is that it is strictly adaptive in style ("only sociology, no politics"), an approach defended by Axelrod with the observation that people often rely on social influence instead on independent analysis.

Agents and medium:
- The agents in Axelrod's model are "actors" which are placed on fixed "sites".
- Actors are individuals with different beliefs, attitudes, and behaviour.
- The term "culture" is used to indicate the set of individual attributes that are subject to social influence.

Behavioural rules:
Axelrod's unique approach of modeling social influence:
- The effect of one cultural feature depends on the presence or absence of other cultural features.
- Communication is most effective between similar people and therefore similar indivuals are more likely to influence each other than dissimilar individuals.

Selection #3 of Building Blocks

Inspired by Axelrod's model, three more building blocks are imported:

Selection #3 of Building blocks

expressing a hunch with regard to the valorization of workers and the dissemination of culture

- New building blocks from the theme "Complexity":
  - *Order*
  - *Evolution*

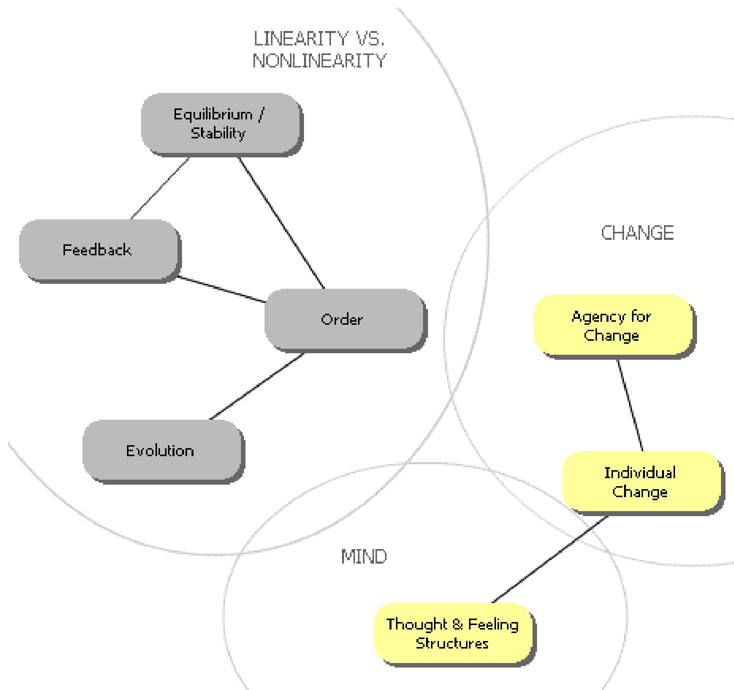


Figure 51 Building blocks that support the hunch about valorization of the worker and dissemination of culture.

Perspective #3 on Quality of Recovery

based on insight into endogenous change

Measures taken:
Our first perspective on the management of municipal solid waste considered an approach that sought implementation of a set of measures that were designed to improve the quality of recovery. These measures were:

- to have institutions for learning offer improved training opportunities and more diffusion of know-how;
- to increase the frequency of environmental education and to broaden its scope;
- other ways to improve the qualification of the worker.

Propagation of changes:
Changes as consequences of these measures propel two self-reinforcing feedback loops:

- A "learning" loop with social benefits:
    - increased participation of civil society;
- An "innovation" loop, that is enforced by the "learning" loop, with environmental and economic benefits:
    - improved quality of recovery;
    - improved product reintegratability;
    - increased applicability of technology.

This perspective was designed to discover mechanisms that explain the dynamics of "learning" and "innovation" in terms of endogenous agency for change. Central in this perspective was the interaction between actors. An interesting example concerns the valorization of the worker. Mechanisms for "learning" are not limited to training, diffusion of know-how and environmental education (all exogenous) but include "social influence" and the dissemination of culture (beliefs, attitudes, behaviour).

Expected benefits:
The expected benefits of this approach are not limited to an improved quality of recovery, but include:

- Environmental benefits:
    - Less residues;
- Improved product reintegratability;
- Social benefits:
    - Improved quality of life;
    - Promotion of civil society;
- Economic benefits:
    - Less industry rejects;
    - Less energy consumption;
    - Increased applicability of technology.

APPENDIX C PART 1, BLUEPRINT SCORE SHEETS

SYSTEM DYNAMICS

1. Introduction

What is System Dynamics (SD)?

System dynamics (SD) is a field for better comprehension of systems, and especially for understanding how things change through time. Questions in SD deal with system behaviour over time that follows from its structure. Jay Forrester, the founder of SD, claims that frequently mental models of systems (held in a person's mind) are right about systems structure, but draw wrong conclusions about systems behaviour (Forrester 1971). In SD, computer simulations are conducted to achieve correct conclusions.

SD simulations involve three modeling languages:

- conceptual building stones. In all system dynamics computer simulations, systems are conceptualized as continuous networks of interconnected flows, i.e. quantities (e.g. resources) that move around in the system. The main variables in any SD simulation model are stocks (or levels) that are used to keep track of how quantities accumulate over time in various parts of the system (i.e. they are the system's memory). A flow, then, is defined as a movement of a quantity from one level to another. In the SD conceptual modeling language stocks and flows are the essential building stones for the representation of systems structure. They allow the modeler to address questions that deal with systems behaviour generated by (multiple) feedback loops.
- mathematics. Mathematically speaking, the continuous systems are represented with (often non-linear) differential equations.
- computer program. In order to represent a continuous system on a digital computer, approximation algorithms have to be used.

Why SD?

Meadows (1976) states that system dynamics, when it was founded by Forrester, amalgamated three fields [1] control, feedback, and self-regulation [2] cybernetics (i.e. the role of information in [1]), and [3] organization theory (e.g. how can the structure of an organization be improved? how can decision-making in an organization be improved?). From this historical viewpoint, the rationale for SD can be interpreted in at least two different ways:

- philosophical rationale. Closely related to the SD field was systems thinking, defined as a thought process that involves 1. seeing interrelationships (feedback loops) instead of linear cause-effect chains, and 2. seeking processes of change over time rather than snapshots. Of course, systems thinking has evolved since then.
- problem-solving rationale. SD was partly motivated by the expectation that with a better comprehension of systems, one can redesign structure or policies to improve behaviour. Forrester equates problem-solving to identifying leverage points, i.e. policies which can yield large changes in a system (Forrester 1971). When thinking about policies, the support offered by SD to test and, if necessary, correct mental models becomes even more crucial because behaviour of social systems (as opposed to natural systems) is likely to be counterintuitive:
    - Social systems are inherently insensitive to most policy changes that people choose in an effort to alter the behavior of systems. In fact, social systems draw attention to the very points at which an attempt to intervene will fail. Human intuition develops from exposure to simple systems.
    - Social systems seem to have a few sensitive influence points through which behavior can be changed.
    - Social systems exhibit a conflict between short-term and long-term consequences of a policy change.

(Forrester 1971)

How does SD work?

In current SD practices, the system dynamics professional is supported by commercially available toolsets (e.g. Vensim, IThink). These toolsets incorporate tools for both conceptualization and formalization of SD simulation models:

- Conceptualization:
  - causal diagramming;
  - stocks-and-flows diagramming;
  - reference behaviours and archetypes;

- Formalization:
  - system dynamics simulation;
  - graphical functions;
  - sensitivity analysis;
  - time series validation.

See Akkermans 1997 for a descriptions of each, as well as their illustration of their uses in case studies.

2. Evaluation Against the BLUEPRINT Criteria

	Back-Loops (Reflexivity) Inputs about relationships between higher level system components and subsystems should be treated as parallel voices, not absolute truths.
BL.1	Are fundamental uncertainties about relationships between higher level system components and subsystems expressed?
BL.2	Do "voices of control" dominate, or "voices emphasizing emergence and self-organizing processes"?
BL.3	Do "voices centered on the individual" dominate, or "voices of decentred agency"?

BL.1: No. In SD higher level system components and susbsystems typically are characterized using a only small number of variables ("stocks"). If for some conceptualization of the target system the relationships between variables are hard to specify in the formal SD language, the SD modeler will most likely try other conceptualizations (for example introduce new variables, or use a different combination of concepts from the SD language). There is a risk that by doing so, fundamental uncertainties about relationships end up hidden within the conceptualization of the target system.

BL.2: Voices of control. Typical SD applications seek to redesign the structure of the target system so that there are improved control mechanisms in the system (self-regulation through feedback) that lead the system to produce more desirable behaviour. Redesign involves manipulating chains of causal relationships, with humans (the designers) being rational obervers "outside" the system.

BL.3: Voices centered on the individual. The SD conceptual language contains concepts that allow information about the system to play a role in the "decision rules" that determine its behaviour. However, the processes of how those decisions[25] are reached cannot be made explicit in the SD language. Consequently, the more the modeler relies upon these concepts, the more difficult it gets to fully understand the model and what the study of that model may tell about the target system. These difficulties get more serious when the processes behind decisions involve individually acting agents that live in a mutually created and sustained world.

Score:

The design criterion Back-Loops (Reflexivity) is not met.

[25] In SD "decisions" are adjustments in a system's structure that do not necessarily follow from goal-seeking behaviour, but from activities in general (e.g. the rate of a flow adjusts when a stock reaches a certain level).

Human / Environment Human goal-seeking behaviour is represented and non-measurable aspects are taken into account.	
UE.1	Are goals of human subsystems, or goals of individual agents within these systems, represented?
UE.2	Are processes to pursue these goals represented?
UE.3	Are non-measurable aspects represented?
UE.4	How is the imperfect nature of human-decision making dealt with?
UE.5	Do objectifying voices dominate, or intersubjective / relational voices?

UE.1: Yes. Goal-seeking behaviour is an important concern in SD and is associated with (negative) feedback loops. "Control decisions" (see BL.3) attempt to adjust a system level to a value given by a goal introduced from outside the loop.

UE.2: No. SD models fall short in representing human goal-seeking behaviour because the processes of how control decisions are reached cannot be made explicit (see BL.3).

UE.3: Yes. In SD graphical functions are used to overcoming the lack of measured data about aspects of the model. The modeler decides on the average shape of a relationship (e.g. S-shaped, gradual decline). It is not crucial to have exact values for points on the graph; it is the overall pattern that counts.

UE.4: Sensitivity analysis[26] may help to check whether decision rules can be legitimately used[27]. For example, the modeler might find that under different category of inputs the system appears to 'switch' from one mode of behaviour to another. Such sensitivities point at a possibility that (imperfect) human goal-seeking behaviour may have to be represented. Because the SD language offers little means to do so, the modeler most likely will proceeed constructing alternative representations that cover the different modes of system behaviour.

<u>Score:</u>

The design criterion Human/Environment is not met.

Problem-oriented At some point, ends (goals, objectives) are placed vis-à-vis means (strategies, measures).	
PR.1	Are ends (goals, objectives) represented?
PR.2	Are means (strategies, measures) represented?
PR.3	Is there a confrontation of ends vis-à-vis means?
PR.4	Does this confrontation touch upon the 'big issues'?

PR.1: Yes. Goals are associated with stocks and are always quantitative.

PR.2: Yes. Measures are associated with decision rules and are always quantitative.

PR.3: Yes. Nice examples are management flight simulators (MFS) built with SD. On top of the system representation are placed a few key inputs (measures) and key outputs (indicators associated with goals).

[26] In sensitivity analysis, one changes the value of a chosen variable considerably and looks at the impact of that change on another model variable. If the model's output is hardly altered, then one need not to worry too much about that particular variable. If considerable changes do occur, then one knows that one has a key model variable at hand that requires further attention.
[27] In SD studies often only the values of a limited number of variables are of crucial importance for the overall system behaviour. In most simulation models, the values of most model variables can be changed considerably without any significant change occurring in system behaviour. Indeed this is an important rationale for the use of decision rules - likely to be rough and little expressive in comparison to what really happens - for specifying relationships between variables.

The inputs can be adjusted by the user over simulation time, so there is direct interaction with the system. The impact of the user's actions can be counterintuitive (e.g. accumulations over time) which makes MFS nice tools for learning.

PR.4: Yes. This is claimed to be one of the strengths of the SD approach. SD encourages the modeler to skip over limitations, e.g. lacking knowledge or information, and to focus right away on the essential system aspects. The World3 model by Meadows (Meadows et al.) is a good example of a SD model that addresses big issues in spite of many uncertainties. The impact of this model has been considerable.

Score:

The design criterion Problem-oriented is met.

Integrative Modeling integrates what is already there (science, models, expert opinions).	
INTg.1	Which manner is used to codify (sometimes tacit) knowledge from different sources?
INTg.2	Is the structure of the integrated problem representation clear or has it become too complicated?
INTg.3	Is the level of aggregation acceptable or is it too high?
INTg.4	Can different types of uncertainties, introduced along the process of integration, be easily recognized?
INTg.5	Does the model represent in transparent manner the inputs of those involved in the modeling process; will they have confidence in the integrated representation?

INTg.1: Systems are conceptualized as continuous networks of interconnected flows, i.e. quantities (e.g. resources) that move around in the system. Codification of knowledge happens with two elementary building stones: stocks and flows. Typically the model is first conceptualized using diagramming techniques and then formalized using quantitative statements.

INTg.2: Though visualization with diagrams helps keeping SD models from becoming inaccessible, there is a certain risk that integration makes the structure of a model too complicated. This risk is especially apparent in case of reflexivity (see BL.3). Sensitivity analysis may help to distinguish between more important and less important variables (see UE.4).

INTg.3: Typical problems with aggregation in SD arise when modeling spatial problems. SD offers little flexibility when the modeler wants to consider different scales, unless he wants to radically increase the number of variables. Of course one can always emulate with SD the behaviour of other models that are built with more flexible instruments. Yet this practice introduces another source of uncertainty into the modeling.

INTg.4: In SD conceptualizations of models do not direct attention to the type of uncertainties that are introduced along the process of integration. Of course, the formalization of a model may include probability-based parts, but this practice may hide sources of uncertainties rather than bringing them to the foreground.

INTg.5: This is an important concern in SD modeling. Typically modelers have a hard time to bridge the gap with decision makers (who might be very important contributors of knowledge). Methodologies for participatory modeling with SD (Akkermans 1995, Vennix 1996) aim to overcome this obstacle.

Score:

The design criterion Integrative is partly met.

Interactive Modeling is quick, participatory and offers valuable scripts.	
INTa.1	Are responses produced timely, or afterward only to justify past events?
INTa.2	What is the interaction between people (model users) and the model? Is there participation during the modeling process?

INTa.3	What kind of scripts are offered? (intuitive / counterintuitive)

INTa.1: The construction of SD models can be a laborious, time-consuming endeavour. Especially the formalization step can be laborious. For this reason, projects may concentrate only on constructing a SD conceptualization of a model. They also may rely on generic structures that are well understood (e.g. overshoot and collapse).

INTa.2: The diagramming techniques in the SD toolset lend themselves for use in a participatory setting. Participatory modeling was already mentioned (see INTg.5). Akkermans (1995) states that it is very important that the facilitator is highly skilled.

INTa.3: Earlier was stated that the problem-solving rationale for using SD is related to the counterintuitive behaviour of social systems.

Score:

The design criterion Interactive is partly met.

APPENDIX C PART 2, BLUEPRINT SCORE SHEETS

INTEGRATED ASSESSMENT

1. Introduction

What is Integrated Assessment (IA)?

Integrated Assessment (IA) can be defined as a process: "Integrated Assessment is a multi- or interdisciplinary process of structuring knowledge elements from various scientific disciplines in such a manner that all relevant aspects of a social problem are considered in their mutual coherence for the benefit of decision-making" (Rotmans 1999).

Designs of IA processes respect at least three design principles:

- Integration. In IA integration is understood as causally linking processes (physical, monetary, information, policy) relevant to a social problem. Rotmans (1999) states that integration is problematic because it requires coupling long-term processes with short-term processes, higher scale processes with lower scale processes, and equilibrium processes with non-equilibrium processes. Models containing process knowledge (inputs of the IA process) are likely to be complicated, complex and disaggregated. Thus IA processes are about ways to simplify and to aggregate these inputs.
- Multi- or interdisciplinarity. Disciplinary knowledge concentrates on social subsystems (socio-cultural, economic, environmental) yet crucial changes occur at the cutting edge of the social subsystems rather than within the subsystems themselves. In IA processes new knowledge is produced from multi- or interdisciplinary backgrounds.
- Participation. In IA processes participatory methods and tools are used to bridge at least two gaps:
    - the gap between scientists (who supply facts, uncertainties and hypotheses about complex social issues) and decision-makers (who demand information about these issues);
    - the gap between natural scientists (who develop and apply practical integrated tools such as models, indicators and scenarios) and social scientists (who hold a reflexive viewpoint on the IA process).

Why IA?

The rationale for integrated assessment is philosophical. IA deliberately seeks the position of an a-priori integrated point of view on social problems. Rotmans defended this position, observing that "the world around us has changed" and describing four trends:

- interconnectedness (global, international processes interfere with local, national processes);
- technological development (growing amount of information available to the individual, influence of technological development on social and culture patterns);
- shorter rotation time of all sorts of processes;
- increase of knowledge about the interactions between social, economic and ecological processes.

Thus IA is a deliberate shift away from traditional philosophies about modeling toward a more holistic, postmodern one:

Away From	Toward
Scientists simulate the world from behind their desk.	Scientists strive for an integrated worldviews (through interaction, dialogue, mutual learning).
Decision-makers are ambivalent and inarticulate about their wishes and requirements.	Decision-makers go more deeply into analytical instruments in order to articulate their wishes and requirements in an unequivocal way.
Models are fully discipline-oriented, overly detailed, inflexible, inaccessible for non-expert users, and the meaning of their results is hard to communicate.	Models are simple, flexible, and can be used 1. to explore (broadly, roughly) the interactions and feedback mechanisms between subsystems, 2. to structure scientific knowledge (by including meta-information about critical uncertainties, gaps in scientific knowledge, weaknesses in discipline-oriented expert models) 3. to communicate complex scientific issues to decision-makers, disciplinary scientists, stakeholders, and the general public.
Attitudes about uncertainties are insensitive to different types of uncertainties (e.g. the belief that more knowledge and information will reduce all types of uncertainties).	"uncertainty management"
Scenarios are dogmatic predictions.	Scenarios broaden perspectives, raise questions, and challenge conventional thinking.
Studies rely on quantitative knowledge only.	Studies integrate quantitative knowledge with qualitative knowledge.

How does IA work?

Although modeling is central in IA processes, the IA toolset incorporates several other methods and tools:

- analytical methods and tools:
  - models;
  - scenarios;
- participatory methods and tools:
  - the dialogue-method;
  - policy exercises (simulation games);
  - mutual learning methods.

For a description of each see Rotmans (1999).

2. Evaluation Against the BLUEPRINT Criteria

	Back-Loops (Reflexivity) Inputs about relationships between higher level system components and subsystems should be treated as parallel voices, not absolute truths.
BL.1	Are fundamental uncertainties about relationships between higher level system components and subsystems expressed?
BL.2	Do "voices of control" dominate, or "voices emphasizing emergence and self-organizing processes"?
BL.3	Do "voices centered on the individual" dominate, or "voices of decentred agency"?

BL.1: Rotmans and Van Asselt (2001) stated that "Current methods of uncertainty analysis [sensitivity analysis, validation and several others] suffer from the fact that they address only uncertainties in model quantities and neglect the structure of the model itself. They also stated that " To date, there is no alternative crystallized portfolio of methods that enables IA modelers to deal with inherent uncertainty in their daily practice."

Rotmans and Van Asselt proposed a pluralistic approach to uncertainty management. A perspective is defined as "a coherent and consistent description of the perceptual screen through which (groups of) people interpret or make sense to the world and its social dimensions, and which guide them in acting". Examples are the "hierarchist", "egalitarian", "individualist" and "fatalist" perspectives used by these authors in studies on climate change. By specifying alternative values for the selected model uncertainties, a chain of perspective-based model formulations is created, or so-called "model routes" (Van Asselt and Rotmans, 1995, 1996; Rotmans and de Vries, 1997). These multiple model routes are alternative ways of looking at model inputs, parameters and relationships, taking into account the bias and preferences of a number of stereotypical perspectives.

BL.2: With the pluralistic approach to uncertainty management, choices of "decision rules" (see System Dynamics BL.3) become relative to the uncertainties addressed and the perspectives defined. Yet the processes behind the "decisions" are still not represented in the model. Unless ways are found to create model routes that express aspects of the processes behind the decisions, perspectives are unlikely to reflect voices of emergence and self-organizing processes.

BL.3: Voices centered on the individual; for the same reason as is given in BL.2.

Score:

The design criterion Back-Loops (Reflexivity) is not met.

Human / Environment

Human goal-seeking behaviour is represented and non-measurable aspects are taken into account.

UE.1	Are goals of human subsystems, or goals of individual agents within these systems, represented?
UE.2	Are processes to pursue these goals represented?
UE.3	Are non-measurable aspects represented?
UE.4	How is the imperfect nature of human-decision making dealt with?
UE.5	Do objectifying voices dominate, or intersubjective / relational voices?

UE.1: Yes. Representations of human subsystems most likely include "control decisions" (see System Dynamics UE.1) if only to impose limits on the range of their behaviours so that the modeler has an overall idea of where the integrated model might be going.

UE.2: IA studies may benefit from policy exercises (simulation games) to gain insight in processes of goal-seeking. A policy exercise can be described as "a flexibly structured process designed as an interface between scientists and policy makers in which a complex system is represented by a simpler one with relevant behavioural similarity, and from which decision-making is part through human participants." A policy exercise is a way to get information on human behaviour and policy preferences necessary for the assessment the analysts produce. It is however not clear how that information could be represented so that it can be incorporated into an IA model.

UE.3: Participatory methods are able to integrate quantitative with qualitative knowledge (Parson 1996). Qualitative knowledge cannot (yet) be grasped by IA models. In this way, participatory methods can complement IA models and scenarios[28].

UE.4: IA is an innovative field that aspires to give a more prominent role in IA studies to the reality that human decision-making occurs under circumstances of lack of knowledge and (different types of) uncertainties. Yet a gap remains between aspirations and the capability of IA methods and tools to deal with this reality. Rotmans and Van Asselt repeatedly refer to this gap as the "inmaturity" of IA.

[28] Scenarios can be defined as "archetypal descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments." Different types of scenarios can be distinguished: quantitative scenarios based on the use of models, qualitative scenarios based on narratives, and hybrid scenarios based on participatory methods. They can be used to: 1. articulate key considerations and assumptions, 2. blend quantitative and qualitative knowledge, 3. identify constraints and dilemmas, and 4. expand thinking beyond the conventional paradigm.

UE.5: The use of "perspectives" (see BL.1) helps to reflect the tensions among objectifying voices and intersubjective / relational voices.

Score:

The design criterion Human/Environment is partly met.

Problem-oriented At some point, ends (goals, objectives) are placed vis-à-vis means (strategies, measures).	
PR.1	Are ends (goals, objectives) represented?
PR.2	Are means (strategies, measures) represented?
PR.3	Is there a confrontation of ends vis-à-vis means?
PR.4	Does this confrontation touch upon the 'big issues'?

PR.1: In general, IA models attempt to portray the social, economic, environmental and institutional dimensions of a problem in question. The social dimension aims at describing the social behaviour of people in terms of demographics, consumption behaviour, migration and urbanisation. The economic dimension focuses on the production and consumption of resources, capital and labour. The environmental dimension deals with the physical, biological and chemical transformation of substances, and their penetration in the natural environment. Finally, the institutional dimension involves the palette of policy options and measures in terms of financial measures, legislative measures, education and R&D programmes.

Weyant et al. (1996) classified IA models in 2 categories: i) policy optimisation models, which try to optimise key policy variables given certain policy goals, and ii) policy evaluation models, which try to evaluate the environmental, economic and social consequences of specific policy strategies.

PR.2/PR.3/PR.4: Yes. See PR.1

Score:

The design criterion Problem-oriented is met.

Integrative Modeling integrates what is already there (science, models, expert opinions).	
INTg.1	Which manner is used to codify (sometimes tacit) knowledge from different sources?
INTg.2	Is the structure of the integrated problem representation clear or has it become too complicated?
INTg.3	Is the level of aggregation acceptable or is it too high?
INTg.4	Can different types of uncertainties, introduced along the process of integration, be easily recognized?
INTg.5	Does the model represent in transparent manner the inputs of those involved in the modeling process; will they have confidence in the integrated representation?

INTg.1: Myriad codifications can be used to interconnect problems, cause-effect relationships, issues, scales, uncertainties, and so on. The process of codification and integration depends on simplification and aggregation.

INTg.2: Repeatedly the concern is uttered that problems, issues, uncertainties etc. tend to accumulate along the IA process. To help keeping the IA process manageable, many alternative typologies are proposed in the literature, some of which are more useful than others in this respect. Further, IA also may focus on a meta-level, where things are simpler, more abstract and there is less detail.

INTg.3: See INTg.2

INTg.4: Rotmans and Van Asselt (2001) stated that in IA modeling, technical, methodological and epistemological uncertainties materialize respectively as uncertainties in model quantities, uncertainty about model form and uncertainty about model completeness. Of these types, uncertainty about model completeness is the most fundamental and crucial for the quality of the IA model (epistemological uncertainties) and is addressed in the model validation phase. However, complete validation is impossible in case of complex systems due to inherent uncertainty (especially due to ignorance and indeterminacy) (Oreskes et al., 1994). To express the limits to validation exercises, model validation is also referred to as testing model performance. A fourth type of uncertainty relevant includes so-called model operation uncertainties. These uncertainties occur partly due to the hidden flaws in the technical equipment (especially numerical errors and bugs in hard- and software), but above all due to accumulation of uncertainties propagated through the model (Beck, 1986; van Asselt and Rotmans, 1996).

Rotmans and Van Asselt then asked the logical question: How is uncertainty managed in IA? Basing themselves on a review of eight approaches for uncertainty analysis (including plurastic uncertainty management, see BL.1) they reach the conclusion: "Uncertainty analysis lacks a toolkit that enables to address salient technical, methodological and epistemological uncertainties in an adequate manner as central activity in Integrated Assessment."

INTg.5: To increase transparency of the IA process and confidence, analytical methods and tools are complemented with participatory methods and tools. Yet the participatory method or tool can have the same flaw (lack of transparency either for participants or for peers that did not participate).

Score:

The design criterion Integrative is met

Interactive Modeling is quick, participatory and offers valuable scripts.	
INTa.1	Are responses produced timely or afterward only to justify past events?
INTa.2	What is the interaction between people (model users) and the model? Is there participation during the modeling process?
INTa.3	What kinds of scripts are offered? (intuitive/counterintuitive)

INTa.1: IA studies aim to produce timely responses. IA models should be flexible and rapid tools that permit rapid prototyping of new concepts and scientific insights. Scenarios should help to think about the future (e.g. anticipate on future dilemmas).

INTa.2: Trends in IA are use of participatory methods and tools both for constructing models and for designing scenarios.

INTa.3: Concerns about intuitive/counterintuitive scripts are overshadowed by concerns about coherence and consistency. Integration is likely to involve a set of crucial assumptions along different temporal and spatial scales and different aggregation levels. Thinking about scripts in IA is concentrated on the use of scenarios (see UE.3). Rotmans and Van Asselt (1999) state about scenarios: "In order to fulfil their communicative and decision-supportive role, scenarios need to be coherent and consistent. The aspect of coherency refers to the inclusion of all relevant dimensions, and all relevant interlinkages between the various processes considered. Consistency implies that key assumptions done in the scenarios are checked among different scales, sectors and issues. For example, assumptions with regard to future energy use should be checked with assumptions regarding future land and water use."

Score:

The design criterion Interactive is partly met.

APPENDIX C PART 3, BLUEPRINT SCORE SHEETS

AGENT-BASED SIMULATION

1. Introduction

What is Agent-Based Simulation (ABS)?

Agent-based simulation is a technique in computer modeling that allows large populations of human-like software agents to make decisions and interact with one another. An agent is an atomic entity that acts with some individuality or autonomy within a larger whole. If the target system is a social system, agents typically represent people or human organizations.

Before any simulations can be conducted, the modeler should equip agents with properties and a behavioural repertoire. Typically the modeler specifies rules for how individual agents behave (e.g. how they move around, how they interact with other agents). These rules can be few and simple, using only little pieces of information about the agent world.

Once the rules have been specified, the simulation can be run as often as desired, and aggregate outcomes can be observed that are generated by the interactions of the agents. If the target system is a social system, the modeler would hope for some resemblance to social phenomena in the real world, requiring outputs that show some regularities (total chaos would not be very interesting).

By repeating the simulation with different starting situations and with different rules, the modeler learns more about the relationships between the actions of individual agents and the aggregate outcomes (provided that these relationships are tractable). This learning process may help the modeler in theorizing about the relationships between individual behaviours and collective outcomes in the real world.

Why ABS?

- philosophical rationale: Already much has been said about the philosophical rationale for agent-based simulation. In the first chapter a historical viewpoint was sketched that put agent-based simulation in a common perspective with two fronteers: 1. the kind of questions raised by complexity research at the Santa Fe Institute, and 2. new ways of doing social science. The bird's eye view in this chapter allowed us to be more precise: agent-based (social) simulation comes into its own when the theoretical context for modeling has not stabilized yet, the two cases being complexity and constructivism.

- problem-solving rationale: From a practical point of view, the main rationale for agent-based simulation is the limited usefulness of equation-based computer models for describing certain real life phenomena. Agent-based simulations can cope with complex, dynamic systems with a lot of interactions and an element of randomness. These simulations are effective in capturing (social) phenomena that involve non-linear effects, i.e. when small variations make huge differences. Such phenomena are very difficult to describe in mathematical equations. Moreover, the approach is inherently interdisciplinary because its only requirement is the specification of local rules for individual agent behaviours, and on that (micro-)level the boundaries between disciplines become meaningless.

How does ABS work?

In the bird's eye view in this chapter we saw that agent-based (social) simulation urges us to rethink good modeling (or simulation) practice. A methodology that fits that picture is proposed by Chris Goldspink:

axiomatic base	←	precepts ↓	←	phenomena class
↓		meta-model ↓		↑
theory	↔	**model**	↔	**phenomena of interest**

Figure 52 A methodology for agent-based (social) simulation (Goldspink 2000)

1) Initial study of the phenomena using situated research is followed to identify fundamental precepts and to choose meta-model elements as a guide to development of a specific simulation. This research will also contribute to initial theory development.
2) Two-way tests between theory - model and model - phenomena of interest. Systematic experimentation using the model. The model behaviour guides investigation of the phenomena, which, as it can be approached only in situ, must be studied using situated research methods. At the same time the model behaviour is systematically compared with behaviour predicted by the theory. The simulation model forms the core to the investigation, providing the basis for theory elaboration and development and for testing the theory for empirical validity.
3) The meta-model serves to formalise precepts associated with the broad class of phenomena under investigation. It provides a foundation set of assumptions for the subsequent simulation. (Goldspink 2000)

The two-way testing provides rigour to the methodology, which would be lacking if model and (weak) theory were kept informal (leading to hypotheses that are difficult to falsify).

2. Evaluation Against the BLUEPRINT Criteria

	Back-Loops (Reflexivity) Inputs about relationships between higher level system components and subsystems should be treated as parallel voices, not absolute truths.
BL.1	Are fundamental uncertainties about relationships between higher level system components and subsystems expressed?
BL.2	Do "voices of control" dominate, or "voices emphasizing emergence and self-organizing processes"?
BL.3	Do "voices centered on the individual" dominate, or "voices of decentred agency"?

BL.1: In agent-based simulation relationships between higher level system components and subsystems are a consequence of interactions and decision-making of agents at lower levels[29]. Through our simulations we learn more about the relationships between the actions of individual agents and aggregate outcomes. We may hypothesize that the overall system behaviour of interest cannot be reduced to individual agent behaviours. A measure of complexity specific for the chosen modeling language could express the limits to formulate that overall behaviour, provided that such measure is available.

BL.2: Because of the novelty of complexity theory and the bottom-up approach in many application fields, currently voices emphasizing emergence and self-organizing processes tend to dominate in agent-based simulations. Yet a proper articulation of these voices can be very difficult. The difficulties can be illustrated with the problem of autonomy of agents. A crucial concern when designing agent-based simulations is the

[29] Nothing keeps the modeler from defining agents on multiple system levels, including the higher levels. For instance in simulations of human organizations it is not uncommon to use multilevel models (e.g. "teams" are agents that comprise of agents, "people", on a lower level) and to specify sets of rules on each level.

specification of the behavioural repertoire of agents. The experiment designer can (involuntarily) end up specifying rules that are essentially not very different from "decision rules" in top-down approaches like system dynamics (see System Dynamics BL.3), thus still hiding the processes behind the decisions. To make things worse, such biases in agent-based representations are even more difficult to uncover than in equation-based models. This will not happen if the agents can be designed to be autonomous, i.e. independent of any preconceptions about "good" or "bad" decisions by the experiment designer. Antunes (2000) proposes a design that covers both agent architecture and experimental methodology.

BL.3: Because of the novelty of the bottom-up approach in many application fields, currently voices of decentred agency tend to dominate in agent-based simulations. Yet the influence of the individual and the collective in systems of human agents is two-way. More reflexive designs of agent-based simulation models may be easier to conceive if we have available new conceptions of power as influence in today's human organizations and societies (Castelfranchi 1995).

Score:

The design criterion Back-Loops (Reflexivity) is partly met.

Human / Environment

Human goal-seeking behaviour is represented and non-measurable aspects are taken into account.

UE.1	Are goals of human subsystems, or goals of individual agents within these systems, represented?
UE.2	Are processes to pursue these goals represented?
UE.3	Are non-measurable aspects represented?
UE.4	How is the imperfect nature of human-decision making dealt with?
UE.5	Do objectifying voices dominate, or intersubjective / relational voices?

UE.1: A goal that is implicit in the concept of "agent" (see Goldspink 200x) is survival; to persist in its environment and to adapt to changes in that environment (see UE.2). Nothing keeps the experiment designer from extending the behavioural repertoire of agents with goal-seeking behaviours that are associated with other goals

UE.2: A starting point for representation of goal-seeking processes is to examine the roles of plasticity and variety. Plasticity means that an agent's behaviour may be influenced by changes in environment (system parameters) and may in turn alter those parameters. Variety means that the range of influences is very large. The experiment designer may extend this basic behavioural repertoire - that follows from plasticity and variety - by endowing agents with abilities to communicate with other agents, to accumulate knowledge about its environment, cognition, and so on. Yet more sophisticated agent designs may be redundant for representation of goal-seeking behaviours. Goldspink (2000) states that such extensions are not necessarily required; i.e. what seems to be communication between agents, or knowledge creation and use, may in fact be fully explainable with the roles of plasticity and variety. These considerations are part of the so-called "minimal agent"-discussion among agent-based simulation theorists.

UE.3: Technically speaking, agent-based simulation allows representation of non-measurable aspects. Theorists in the in the agent-based simulation field have already put effort into the development of representations of cognition (e.g. moving from simplistic sets of preferences to more realistic representations that include beliefs, desires, values, etc.), sociality, emotions, and so on. Yet there is still a large gap between the relevance that theorists claim for these aspects and the share of simulations that actually incorporate them (David, Sichman and Coelho 2003).

UE.4: Designers of agent-based simulations can choose from several computer algorithms to represent decision-making processes. Very popular are genetic algorithms - or the so-called hill-climbing methods - that allow decisions to be achieved even when neatly structured decision-making is impossible (for example when the number of alternatives to be considered is very large). Computer algorithms that deal more explicitly with the imperfect nature of human decision-making are based upon some cognitive representation of decision-making (see UE.3). A well-known representation is the beliefs-desires-intentions architecture. Unfortunately these cognitive representations are computationally expensive.

UE.5: The balance between objectifying voices and intersubjective / relational voices depends on the approach chosen for representing decision-making processes (See BL.2, BL.3 and UE.3). Intersubjective /

relational voices are voiced by designs that 1. have agents that are automous to some degree, 2. give attention to cognition, sociality or other non-measurable aspects, and 3. mirror that the influence between the individual and the collective is in human organizations or systems is two-ways.

Score:

The design criterion Human/Environment is partly met.

	Problem-oriented At some point, ends (goals, objectives) are placed vis-à-vis means (strategies, measures).
PR.1	Are ends (goals, objectives) represented?
PR.2	Are means (strategies, measures) represented?
PR.3	Is there a confrontation of ends vis-à-vis means?
PR.4	Does this confrontation touch upon the 'big issues'?

PR.1/PR.2:

- individual agents: Goals of individual agents, and their means to achieve those goals, are explicitly formulated through the rules that determine individual agent behaviour.

- (sub)systems of agents: On the level of (sub)systems of agents, outcomes of individual actions render a rich, diffuse picture that might be interpreted with recognition of goals and means on that level. The exact interpretation(s) that we choose is likely to be informed by the social and biological metaphors that we are familiar with. For example, if the picture is one of complex human organization, we may interpret that picture recognizing "teams" that collaborate on "tasks" (social metaphors) from the background of the complex organization of an "ant hill" (biological metaphor). The use of the simulation model helps to find which balance of social and biological metaphors illuminates the picture best.

- experiment designer (policy goals and options): Most probably, the experiment designer will approach the analysis of his experimental data with certain policy goals and options in mind. In classical experiment designs there will be obvious tensions between policy goals and goals on the level of individual agents (as in experiments about common resource pool management, see Janssen 2000). Typically policies are not made explicit through rules in the model (unlike the use of "control decisions" in top-down approaches, see system dynamics UE.1). Instead, they are associated with crucial parameters that - when assuming different categories of values - make the system switch into different modes (e.g. switches between modes of "competition" and "collaborative" modes in complex human organizations). Very interesting from a policy viewpoint are simulations that point out that part of redesigning or reengineering systems is done by the systems themselves; i.e. that show how systems accomplish self-organized switching between modes.

PR.3: In agent-based simulation the experiment designer has to be (very) selective with regard to a confrontation of ends vis-a-vis means. It is unlikely that a confrontation can be complete (all ends vs. all means). Even very simple, well-focused agent-based simulations can produce very rich experimental data that require analysis from many different angles. Intractability (i.e. our inability to fully understand relationships between individual actions and collective outcomes) is a major concern in the field. Many in the field see that simulation tools can (and should) be significantly improved to facilitate the analysis of rich experimental data. Current trends point into a direction of a next generation of tools that allow us to observe not only behavioural events but also cognitive events, thus enhancing our ability to track more comprehensively what happened in a simulation run.

PR.4: The usability of agent-based (social) simulation as an approach for problem-solving is still largely untested. It has proven its potential usability as an approach to study how fundamental processes work below and before policies. It has also proven its potential usability to create the synergetic energy among disciplines that is necessary to push forward (e.g. highly creative thinking about new conceptions of 'old' problems). The next step is to test the potential usability of agent-based (social) simulation as a tool for problem-solving, which is indeed what this thesis is all about.

Score:

The design criterion Problem-oriented is partly met.

Integrative Modeling integrates what is already there (science, models, expert opinions).	
INTg.1	Which manner is used to codify (sometimes tacit) knowledge from different sources?
INTg.2	Is the structure of the integrated problem representation clear or has it become too complicated?
INTg.3	Is the level of aggregation acceptable or is it too high?
INTg.4	Can different types of uncertainties, introduced along the process of integration, be easily recognized?
INTg.5	Does the model represent in transparent manner the inputs of those involved in the modeling process; will they have confidence in the integrated representation?

INTg.1: The main knowledge base for agent-based simulation should be low-level assumptions which are 'safe' for the given research. Codification of that knowledge happens in several ways: [1:] formal specification of behavioural rules (typically stimulus-response kind of rules) [2:] in a meta-model (see Goldspink's methodology in Figure 52) [3:] as part of an ontology (to make sure that the knowledge base is internally consistent when knowledge from different sources is added).

INTg.2: Leik and Meeker (1995: 465-466) suggest that even when the knowledge base is reasonably safe and complete (see INTg.1) structure will remain unclear unless [1:] every tie from the simulation to the model to the substantive theory is made explicit; [2:] the way each algorithm in the simulation works is laid out so others can judge its appropriateness; [3:] every constraint on variable, parameters, numbers of runs and so forth is justified; [4:] every decision about what to examine and report is made explicit; [5:] all justifications are in light of the substantive interpretations to be made of the model being simulated.

Obviously this is all very time-consuming. Goldspink expects that quasi-structured languages with broad applicability - now being developed in industry, and in the future extended to agent-based social simulation - will accomodate these substantial demands.

INTg.3: The formal languages that are used in agent-based simulation offer a lot of flexibility in working with several levels of aggregation at the same time, and it only requires little effort to change the overall aggregation scheme. One serious concern though is model scalability. Scalability assesses how well the system does useful work as the size and/or complexity of the system increases (David, Sichman and Coelho 2003). Testing of agent-based simulation models should always include tests on scalability.

INTg.4: The crux of uncertainty management is the two-way testing between theory ↔ model and model ↔ phenomena of interest (see Figure 52). It is very important to maintain extensive logs during the simulation study - and especially for each simulation that is conducted. This way we can track when a source of uncertainty is introduced (e.g. a new assumption that is not 'safe'), for what reasons, and how it affects model performance. For example, we may record in our "lab notebook" that with the new assumption model behaviour compares better both with 1. the behaviour predicted by the theory and with 2. the behaviour observed as characteristic of the phenomena. This allows us to think of the new assumption as 'safe'. Ideally we would like this testing to be independent from the simulator used. This source of uncertainty is hard to address methodologically, though procedures have been proposed (e.g. "docking" of models; Axtell, Axelrod, Epstein, Cohen 1996).

INTg.5: The use of a meta-model helps to prevent that valuable inputs are left out just because they could not (yet) be integrated into the model. David, Sichman and Coelho suggest that ontological commitments may increase transparency: "The use of ontologies may take into account the establishment of an ontological commitment. An ontological commitment is an agreement to use the shared vocabulary in a coherent and consistent way. This commitment allows the access to heterogeneous sources of information, which could be otherwise unintelligible." (David, Sichman and Coelho 2003)

<u>Score:</u>

The design criterion Integrative is partly met.

Interactive Modeling is quick, participatory and offers valuable scripts.	
INTa.1	Are responses produced timely or afterward only to justify past events?
INTa.2	What is the interaction between people (model users) and the model? Is there participation during the modeling process?
INTa.3	What kinds of scripts are offered? (intuitive/counterintuitive)

INTa.1: Obstacles that were already mentioned include:

1) assembling a knowledge base that is reasonably safe and complete:
   - Available social concepts may assume away many of the phenomena of interest.
   - We may only find out after many simulations what is the most fruitful balance between social and biological metaphors.
2) conducting simulations:
   - Rich sets of experimental data may have to be analyzed to fully understand relationships between individual actions and collective outcomes.
   - Additional testing may be needed to assess whether the simulation results are independent from the simulator used.
3) communication of simulation results:
   - It may take lot of effort to clarify the structure of the simulation model.

INTa.2: There are examples of agent-based simulation studies that involved participatory methods (Downing, Post-Wahl 2000).

INTa.3: Scripts in agent-based simulation tend to be both intuitive and counterintuitive at the same time. Most times they show overall behaviours that we know well. What is surprising however is the fact that few and simple low-level rules are sufficient to generate these behaviours. Moreover, they allow us to see that conventional assumptions and theory about the relationships between individual actions and collective outcomes can be misleading. They can throw light on phenomena from a complex systems perspective. All considered, agent-based simulation models are autonomous enitities in the world that embody potentially valuable scripts and that are worthy of investigation.

<u>Score:</u>

The design criterion Interactive is partly met.

APPENDIX C PART 4, BLUEPRINT SCORE SHEETS

FRAMEWORK FOR SYNTHESIS

Evaluation Against the BLUEPRINT Criteria

	Back-Loops (Reflexivity) Inputs about relationships between higher level system components and subsystems should be treated as parallel voices, not absolute truths.
BL.1	Are fundamental uncertainties about relationships between higher level system components and subsystems expressed?
BL.2	Do "voices of control" dominate, or "voices emphasizing emergence and self-organizing processes"?
BL.3	Do "voices centered on the individual" dominate, or "voices of decentred agency"?

BL.1: The Framework for Synthesis assumes fundamental uncertainties but does not express them as such. In other words, there is not a "step" in which those uncertainties are assessed[30]. Instead, with the Framework it is assumed that uncertainties are sufficiently big to justify a competition of voices (see BL.2/BL.3)

BL.2/BL.3: Rather than emphasizing one kind of voices over the other, the Framework for Synthesis helps to have these voices compete. For example, by using rapid assessment as a backbone for designing experiments with agent-based simulation, it is ensured that none of those voices are excluded from the modeling process:

Rapid assessment model	Agent-based simulation models
- Voices of control - Voices centred on the individual	- Voices emphasizing emergence - Voices of decentred agency

Score:

The design criterion Back-Loops (Reflexivity) is partly met.

Concluding remark:
To meet this design criterion fully, it is necessary to find a way to facilitate the competition of voices not only by a competition of models, but also based on a prior assessment of the fundamental uncertainties that are involved. A practical measure of complexity could be of particular value.

	Human / Environment Human goal-seeking behaviour is represented and non-measurable aspects are taken into account.
UE.1	Are goals of human subsystems, or goals of individual agents within these systems, represented?
UE.2	Are processes to pursue these goals represented?
UE.3	Are non-measurable aspects represented?
UE.4	How is the imperfect nature of human-decision making dealt with?
UE.5	Do objectifying voices dominate, or intersubjective / relational voices?

[30] For an assessment of fundamental uncertainties about the relationships between higher level system components and subsystems, one would desire a measure of complexity. Such measures have been proposed (for example in Edmonds 1999) and it would be interesting to verify whether they could become part of the Framework.

UE.1/UE.2: The Framework for Synthesis does not offer the tools yet to represent human goals or goal-driven behaviours. This is entirely due to the fact that the baseline model is kept very simple[31] [32]. It is however perfectly possible to develop a set of more advanced baseline models for the Framework.

UE.3: The baseline model incorporates two features for representing non-numerical (non-measurable) aspects of reality: 1) a dynamic representation of social networks and their topological properties, and 2) relative spaces and notions of distance therein. Both features can be used to represent non-measurable aspects like technological trajectories and compatibility, configurations of social ties and trust, social identity, social influence and dissemination of culture (as is illustrated in the case studies).

UE.4: With the current baseline model, the imperfect nature of human-decision making is dealt with in the simplest way: agents are strictly reactive, they simply adapt to situations in medium that is bombarded with events. Consequently, the baseline model is social, not political, that subscribing Axelrod's comment that "people often rely on social influence instead on independent analysis".

UE.5: As stated previously in response to question BL.1, the Framework for Synthesis assumes fundamental uncertainties but does not express them as such. In case rapid assessment is used as a backbone for designing experiments with agent-based simulation, the table in BL.1 can be extended with the following voices:

Rapid assessment model	Agent-based simulation models
- Objectifying voices	- Intersubjective/relational voices

Score:

The design criterion Human/Environment is partly met.

Concluding remarks:

The answers to questions UE.1-UE.4 depend on the kind of baseline model that is available. Certainly, it would mean good progress to have a number of advanced baseline models at hand, preferably targeted to different application domains (e.g., management of innovation, waste management).

However, the issues that those questions raised go beyond the choice of a baseline model. In fact, they point out a likely critique of the Framework for Synthesis. Where does the Framework stand in terms of estimating the potential contribution of complexity thinking and agent-based simulation for strategic planning processes? Is its “best bet” to harness their potential for generating would-be scenarios that surprise and/or inspire us? Or should it be a more ambitious framework that places its bet the on possibility of an accurate representation of human behaviour and even prediction of social outcomes?

Problem-oriented At some point, ends (goals, objectives) are placed vis-à-vis means (strategies, measures).	
PR.1	Are ends (goals, objectives) represented?
PR.2	Are means (strategies, measures) represented?
PR.3	Is there a confrontation of ends vis-à-vis means?

[31] The current baseline model allows specification of agents that are reactive and simply "adapt" to contingencies and events. This means that there is communication (though implicit), action and feedback, but no perception, learning, planning, reasoning, or deciding. Overall, there is one single goal that drives all agent behaviours: "to survive" (i.e. to persist in its medium) – a feature that is a consequence of the "minimal agent" philosophy.

[32] There are good reasons why this baseline model is kept so simple. There are technical constraints (e.g. concerning agent architecture) that are no entirely resolved. Remember also Mesarovic’s comment that "goal-seeking representation requires a deeper understanding of the system and is often difficult, if not prohibitive". Given the circumstances, the wiser strategy seems to be to use a simple way of representing agents and interpret the behaviours of the model in reference to the goal-seeking nature of the system under investigation.

PR.4	Does this confrontation touch upon the 'big issues'?

PR.1/PR.2/PR.3/PR.4: Basically, these issues are resolved by using rapid assessment as a backbone for the experimental design. This allows users to maintain a reference to "the big picture".

Score:

The design criterion Problem-oriented is met.

Integrative Modeling integrates what is already there (science, models, expert opinions).	
INTg.1	Which manner is used to codify (sometimes tacit) knowledge from different sources?
INTg.2	Is the structure of the integrated problem representation clear or has it become too complicated?
INTg.3	Is the level of aggregation acceptable or is it too high?
INTg.4	Can different types of uncertainties, introduced along the process of integration, be easily recognized?
INTg.5	Does the model represent in transparent manner the inputs of those involved in the modeling process; will they have confidence in the integrated representation?

INTg.1: The Framework for Synthesis foresees codification of knowledge in three ways:
- rapid assessment (system components and relations between components);
- building blocks (conceptual building blocks and their interconnections);
- agent-based simulation model (agents and their interactions with other agents and with their medium).

It is illustrated in this thesis how the first two bodies of codified knowledge are first "packaged" by producing perspectives in narrative, which are then embodied in simulation models.

INTg.2: With the Framework for Synthesis it is not a goal to develop "one big model that integrates all knowledge". Instead, users are guided in creating several competing models that all can be very simple. By using rapid assessment as a backbone for process, users maintain a reference to an integrated representation of the problem (for example, results with the partial models can be interpreted in reference to the integrated representation). The overall advantage is that the (simple) structure of the integrated model remains the same, even when parts are explored in more detail.

INTg.3: The Framework presupposes that the level of aggregation in the rapid assessment model is too high, especially when human behaviour is involved. It therefore encourages its users to turn to agent-based simulation models for exploring the implications of micro-level behaviours on macro-level outcomes.

INTg.4: The Framework assumes that there are fundamental uncertainties (see BL.1). On the level of the Framework's tools, there are different ways of expressing other types of uncertainties, each depending on the type of codification of knowledge that is used:
- in rapid assessment the user can define scenario variables (those changes that are beyond our control) and perform a sensitivity analysis;
- in maps of building blocks, gaps reflect uncertainties in theoretical domains.

In agent-based simulation, uncertainties are addressed using multiple runs over a parameter space.

INTg.5: With the Framework for Synthesis, confidence ultimately depends on whether knowledge is communicated effectively, preferably with clear references to the way that knowledge was codified, the aggregation level(s) involved, the uncertainties that were recognized, and so on. The Framework offers two features to improve the effectiveness of communication: 1) the participation in workshops and 2) the use of narrative (when producing perspectives). Also, visualizations of knowledge can be helpful:
- Rapid assessment involves the use of various diagramming techniques (propagation of changes, scorecards, actors vs. strategies and criteria, arenas)
- The building-block card game is partly a visual technique.
- The baseline agent-based simulation model includes features for the visualization of data (e.g. a dynamic graph showing clustering in social networks, representation of relative spaces)

Score:

The design criterion Integrative is met.

	Interactive Modeling is quick, participatory and offers valuable scripts.
INTa.1	Are responses produced timely, or afterward only to justify past events?
INTa.2	What is the interaction between people (model users) and the model? Is there participation during the modeling process?
INTa.3	What kind of scripts are offered? (intuitive / counterintuitive)

INTa.1: The time involved in operating the Framework for Synthesis is a critical factor that needs further testing (notwithstanding that each of the Framework's steps produces results that can be useful in their own right). It is realistic to expect that the whole process can be reduced to 6 months to one year (i.e. from start of workshops to evaluation of the simulated experiments). The process can be accelerated by finetuning the rapid assessment workshops, building blocks and the baseline simulation model, so that they work well with each other. Perhaps the most critical element is the experimentation; in this respect, it is crucial that better tools will come available for systematically exploring the behaviours of a simulation model. Of course, time demands also depend on whether additional efforts for data collection are considered necessary.

INTa.2: Interaction between users – members of a learning action network, members of a modeling team – can occur on several occasions:

- They interact as participants in rapid assessment workshops.
- A workshop can be designed to have both groups work with the building-block card game.

In the preparation of simulated experiments, modelers and LAN members can collaborate to produce perspectives.

INTa.3: Basically, the Framework for Synthesis presupposes that the user is familiar with considering exogenous change in complex systems but not with endogenous change. Consequently, it is anticipated that the rapid assessment workshops will produce mostly intuitive scripts, whereas the simulation experiments will offer mostly counterintuitive scripts.

<u>Score:</u>

The design criterion Interactive is met.