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■ *Research Paper*

Methodologies in Conflict: Achieving Synergies Between System Dynamics and Organizational Cybernetics

Markus Schwaninger*

University of St Gallen, Switzerland

Coping with complexity is at the heart of the systems approach. Several methodologies can be discerned which have proved to possess extraordinary power in dealing with complex issues. System dynamics is a general-purpose methodology for modelling and simulation employed in order to deal with dynamic complexity. Cybernetics has brought forth structural models to enable organizations to deal with the complexity of their environments. The main proposition of this paper is that these two methodological strands show potential synergies. A proposal for leveraging the complementarities of system dynamics and organizational cybernetics is made. The paper also argues that it is necessary to conflate qualitative and quantitative modelling and design approaches, as well as to improve the quality of models and strategies by strengthening the processes of validation. At a higher level of abstraction, the author postulates that, for the sake of relevance, this methodological synthesis is to build upon both the positivist and interpretivist traditions. On this basis, a framework called *integrative systems methodology* is proposed to help actors at different levels to achieve the requisite variety. Copyright © 2004 John Wiley & Sons, Ltd.

Keywords system dynamics; organizational cybernetics; management cybernetics; modelling and simulation; integrative systems methodology

INTRODUCTION

Management science has always aimed at providing concepts and tools for dealing rationally with issues and problems faced by organizations. Over the decades, the practice and the science of management have increasingly been conceived of as tasks for coping with complexity. The speed and uncertainty of events have grown greater, and so have actors' needs for devices to enhance their action potential.

Different methodologies tend to cling to distinct rationalities, and, as any rationality is bounded, so, accordingly, is its respective

*Correspondence to: Markus Schwaninger, University of St Gallen, Institute of Management, Dufourstrasse 48, CH-9000 St Gallen, Switzerland. E-mail: Markus.Schwaninger@unisg.ch

methodology. Different strategies have been pursued to overcome these limitations. The strategy of substituting panaceas for methodologies is often adopted but generally proves to be counterproductive (cf. Flood and Jackson, 1991). The strategy of mixing methodologies arbitrarily becomes bogged down in incommensurabilities, inconsistencies and incoherence.

The purpose of this paper is to develop a strategy which extends the limits imposed by single methodologies, and by approaches which follow exclusively either the qualitative or the quantitative path of inquiry. The strategy advocated here consists in discovering potential synergies of complementary methodologies. These must then be integrated by means of a framework which is purposeful, coherent and theoretically well founded. Such an effort cannot be definitive or final but for the sake of progress it is worth trying to achieve higher levels of methodological rigor and effectiveness.

The argument of the paper proceeds from an overview of the approaches to modelling and design. The methodologies of system dynamics and managerial cybernetics are then analysed as a starting-point for the search for complementarities. Subsequently, potential synergies between these two methodologies are identified, in combination with a proposal to bring together the strengths of the functionalist–structuralist and the interpretive traditions to the modelling of complex issues. The respective complementarities are then combined into a methodological framework designed to help actors achieve the requisite variety. Thereupon, a detailed account of a case study in which that framework was applied will be given. Finally, conclusions are drawn as to the future development of systems methodology.

APPROACHES TO MODELLING AND DESIGN: THE NEED FOR A SYNTHESIS

The effort to provide instruments and methodologies for dealing with complex issues has evolved along two lines:

(1) *A positivistic tradition.* In this tradition, the focus is on dealing with facts, i.e., observables. The pertinent methodologies adopt an objectivist worldview, aiming at observer-independent, accurate representations of reality. They emphasize instrumental rationality, and cultivate structuralist–functionalist approaches. The models generated in this positivistic vein rely heavily on quantification. They are therefore often termed 'hard' methodologies. Under this group we can subsume, for instance, the classical methods and methodologies of operations research (OR), such as optimization, queuing, dynamic programming, evolutionary algorithms, neural networks, etc.

(2) *An interpretivist tradition.* In this tradition, the focus is on interpretations of phenomena or facts. The methodologies of this stream of practice and research highlight the subjectivity of observers perceiving and interpreting the world. In the social domain, they emphasize a discursive approach, i.e., the interaction between multiple perspectives by means of which consensual domains are negotiated and (new) shared realities created. Their underlying rationality is essentially communicational. At the level of modelling, these methodologies rely on qualitative aspects and thereby make use of primarily verbal and graphical expression. Therefore, they are often termed 'soft' methodologies. Under this group we can subsume diverse heuristics rooted in the behavioral sciences. 'soft systems methodology' (SSM, first proposed by Peter Checkland, 1981), which emanated from action research, has become the most visible methodological framework of this kind.

Each of these traditions embodies a distinctive paradigm—a system of norms which has moulded a specific scientific self-understanding of the community which adheres to it. Both paradigms have a great deal to offer in terms of problem-solving capability. However, they also have their limitations. Not being aware of those is what I call the *paradigm trap*. Sir Geoffrey Vickers, the eminent systems thinker, coined the phrase: 'The nature of the trap is a function of the nature of the trapped.' (Vickers, 1972, p. 15). The main limitation is not in the paradigm itself but due to lack of openness and incapability of synthesizing. In order to extend the problem-solving horizon, i.e., to increase the heuristic power of methodologies, overcoming these limitations is the crucial imperative. The challenge is to achieve a cross-fertilization, i.e., to identify potential synergies and synthesize methodologies, where potential complementarities exist.

To achieve some depth of treatment, this paper will elaborate on only one such complementarity and discuss how to bring it about: It exists between the methodologies of system dynamics and organizational cybernetics. Both are well established. Both need completion from without. And both of them are complementary, as has been shown in earlier works (e.g., Schwaninger, 1997).

THE TWO METHODOLOGIES IN PERSPECTIVE

System Dynamics

System dynamics (SD) is a methodology for the modelling and simulation of complex systems, developed by Prof. Jay Forrester at MIT, and grounded in control theory as well as in the modern theory of non-linear dynamics (cf. Forrester, 1961, 1968, 2003; Sterman, 2000). The focus of SD is on issues which are modelled as systems made up essentially of stock and flow variables forming closed feedback loops and simulated as continuous processes. The mathematics of the models is based on differential equations. The dynamics of the systems under study can be captured realistically, and more accurately than in conventional linear or multivariate models, due to the specific modelling technique, namely, the feedbacks and time delays in the loops, and, depending on the model, the interaction between different loops. SD is particularly useful for the discernment of a system's dynamic patterns of behaviour, which may be 'counterintuitive' (Forrester, 1971). SD modelling and simulation have been widely applied in the context of social systems, including economic systems and all kinds of organizations, with particular emphasis on policy analysis and design.

System dynamics was originally conceived as a methodology for modelling and simulating dynamic, non-linear systems to address real-world issues. It grew out of the positivist tradition, even though its originator, Jay Forrester, criticized the limitations of traditional modelling approaches, pioneering an effort to transcend them. Forrester's aim was to make available a methodology which conferred higher 'relevance' upon modelling—i.e., created models that were more realistic and valid than those of traditional OR and economics.

Even though many system dynamicists have embraced a positivist, objectivist worldview, over time new approaches have emerged in the SD community, which have built bridges between the positivist and the interpretivist paradigms. The following enumeration refers to some of these developments, without any claim to completeness:

- *Model validation.* As the methods of model validation have matured, above all with the seminal article by Jay Forrester and Peter Senge (1980), and the work of Yaman Barlas (Barlas and Carpenter, 1990; Barlas, 1996), the epistemological profile of SD modelling was more sharply delineated: SD model validation emerged as a sophisticated set of procedures grounded in a relativistic, holistic philosophy. Validating an SD model thoroughly cannot be limited to a number of statistical tests. It involves a complex methodology of tests, which starts with the framing of the model and thereupon builds up confidence in it via a process which is partly statistical/technical, partly social/communicational.
- *SD-based problem solving.* The multitude of SD-supported consulting projects triggered a movement, spearheaded by David Lane and Rogelio Oliva (1998), among others, which advocated combining 'logic-based analysis' with an 'extended cultural analysis', involving an analysis of the intervention itself, of the social system and of the current political system. This proposal was endorsed by a plea to integrate the views on human agency with those on social structure in SD modelling (Lane, 2001).

- *Group model building.* The need for inter- and transdisciplinary cooperation in the modelling of complex systems led to an increasingly team-based approach. Group model building, on the lines of Jac Vennix's landmark book (1996), became a subject of SD research which draws on the behavioural sciences in particular, and advocates team learning in a controlled process involving both qualitative and quantitative SD.

Management Cybernetics

Management cybernetics is the branch of cybernetics—the science of communication and control in dynamical systems (Wiener, 1948)—which is dedicated to the domain of social systems, particularly organizations, which are purposeful, socio-technical systems exhibiting high degrees of complexity. As far as this paper is concerned, the terms *managerial cybernetics* and *organizational cybernetics* can be used interchangeably. The cybernetic view on socio-technical systems has bred models and methods for the diagnosis and design of organizations. Of major importance in this context is the viable system model (VSM), developed by Stafford Beer (1979, 1981, 1985), the father of management cybernetics. This is a framework for the structuring of organizations as viable systems, which deal with complexity adaptively and recursively.

In a nutshell, the VSM specifies a set of functions which provide the 'necessary and sufficient conditions' (Beer, passim) for the viability of any human or social system. These functions and their interrelationships are specified in a comprehensive theory, the propositions of which can be summarized as follows:

(1) An enterprise is viable if and only if it disposes of a set of management functions with a specific set of the interrelationships identified and formalized in the model:
   - *System 1*. Regulatory capacity of the basic units, autonomous adaptation to their environment, optimization of ongoing activities.
   - *System 2*. Attenuation and amplification to dampen oscillations and coordinate activities via information and communication.
   - *System 3*. Establishing overall optimum among basic units, resource allocation, providing for synergies.
   - *System 3**. Investigation and validation of information flowing between Systems 1–3 and 1–2–3 via auditing/monitoring activities.
   - *System 4*. Dealing with long-term and overall outside environment, diagnosis and modelling of the organization in its environment.
   - *System 5*. Balancing the interaction of '3' and '4', embodiment of supreme values, rules and norms—the ethos of the system.

(2) Any deficiencies in this system, such as missing functions, insufficient capacity of the functions or faulty interaction between them, impair or endanger the viability of the organization.

(3) The viability, cohesion and self-organization of an enterprise depend upon these functions operating recursively at all levels of the organization. A recursive structure comprises autonomous units within autonomous units. Moreover, a viable organization is made up of viable units and itself forms a part of more comprehensive viable units.

The strength of the VSM lies primarily in its diagnostic potency but it is also a powerful conceptual tool to orientate organization design (see, for example, Espejo and Harnden, 1989; Espejo and Schwaninger, 1993). The diagnosis in the case study below will revert to the specifications just given, without going into the details of different recursion levels.

Similarly to system dynamics, managerial cybernetics has emanated from a functionalist–structuralist tradition. Over time, however, many scholars and practitioners who worked with the VSM have emphasized that it is a very useful conceptual 'tool' to support the reflective discourse in an organization, and they thereby read the VSM from an interpretative rather than a functionalist perspective (e.g., Espejo and Harnden, 1989; Harnden, 1989). Processes not only of organizational diagnosis but also of the joint discussion about alternative organizational scenarios and, finally, the design of a desired organization can be supported and their results substantially improved if guided by the VSM. The reason is that it embodies the only theory providing the sufficient structural prerequisites for viability.

POTENTIAL SYNERGIES: NEW METHODOLOGICAL PERSPECTIVES

Cybernetics is not only the root of managerial cybernetics but also one of the sources from which system dynamics emerged. Over time, both SD and managerial cybernetics have pursued their own paths. Two different 'schools' have evolved, by and large independently of each other. In our time, the challenge of complex organizational issues calls for joining forces between the methodologies of both. Such interaction is fertile, given at least two methodological developments. These cannot be completely separated, because they are closely interlinked.

First, SD and management cybernetics have each come up with models and methods capable of tackling issues the other is not equipped to deal with. Both evolved out of a positivist tradition (see above). Secondly, a branch of cybernetics which focuses on social systems and their self-organizing features has bred an epistemology called constructivism,[1] which proceeds from the assumption that realities are constructed by the sensory and cognitive faculties, and likewise by human and social systems (von Foerster and Rebitzer, 1974; von Foerster and Poerksen, 2002). In other words, these 'invent' their environments as they perceive them. Adaptation, in constructivist terms, is a development of structures of action and thought. The idea that the cognitive processes of organizations are essentially processes in which realities are 'produced'—very much in Ackoff's sense of 'creating a desirable future and bringing it about'—has strongly influenced most organizational methodologies. As the interpretivist orientation has largely flowed into constructivism, one might also use the pair of concepts 'Positivism—constructivism' but in any case neither of these terms should be overstressed.

In both fields, cybernetics and SD the limitations of a purely positivist or functionalist approach have been recognized. The functionalistic orientation tends to be narrow in that it tends to instrumentalize human actors as 'purposive' means for the achievement of externally given objectives, while undervaluing their purposeful nature. Purposefulness refers to the critical awareness and self-reflectiveness of humans (Ulrich, 1983, p. 328), whose intrinsic values, goals and preferences are important contributions to an organization. Also, the positivistic approach has largely blurred the fact that different viewpoints lead to different models, and model monism tends to restrict the repertory of behaviour of an organization.

This is not to reject objectivity altogether. Different observers make different distinctions and thereby generate diverse information. For collective learning, the negotiation of shared meanings and the development of shared (mental) models are prerequisites. These communication processes do not aspire to the one ultimate truth but to an objectified model in the sense of an 'objectivity' defined as 'invariance with respect to different observers' (Rapoport, 1953, p. 230). The invariance is never definite but has to be achieved recurrently.

Both fields, cybernetics and SD have learnt from the interpretivist tradition. The limited channel capacities between positivist modellers trying to build up 'objective' models of an organizational issue and those who had to manage that system often led to deficits: modellers 'invented' the wrong problems, and the models were too complicated for managers to understand. In consequence, the models remained unused, with managers doubting their relevance, and modellers feeling frustrated. Each side imputed lack of understanding to the other.

A new age of modelling is coming forth in which the roles of modellers and model users converge. Users become actively involved in the modelling process. Models are developed at conversation pace, i.e., while managers discuss issues, the models are built synchronously, and become their own instruments to enhance their

[1]Not to be confounded with the consensus-theoretical concept of justification and truth in mathematics and physics, going back to Dingler and Lorenzen, which is also called *constructivism*.

repertory of behaviour (cf., for SD: Richmond, 1987; Morecroft, 1988; Vennix *et al*., 1990; Lane, 1992; Hines *et al*., 2003; Ambroz, forthcoming; for Cybernetics: Schwaninger, 1997; Reyes, 2000; Pérez Ríos, 2004). As a consequence, model quality and understanding can be improved, while the discussion gains in transparency, depth and focus. If the process is properly organized and supported, group cohesion is enhanced, both cognitive and emotional forms of motivation are strengthened, and joint commitment is more firmly established (cf. Bruch, 2003; Bruch and Ghoshal, 2003). Altogether, individual and team learning, enabled by the joint construction of shared mental models, takes place (cf. Vennix, 1996).

Recently, both the SD and the management cybernetics communities have shown growing interest in establishing links to other methodologies. In the case of SD, this is documented in several issues of the *System Dynamics Review* (especially Volume 10, Numbers 2–3). A similar interest in the relationship between SD and other approaches may be seen in numerous papers given at SD conferences in recent years. In the case of management cybernetics, first initiatives for joining forces with other methodological schools have been taken (e.g., Moscardini *et al*., 2002).

In sum, the potential synergies are twofold:

(a) The power of cybernetics to diagnose and design organizations for viability and development is united with the capability of SD to make dynamic complexity understandable. In this way, complex organizational issues can be dealt with properly at both levels, content and context.
(b) The gap between the positivist and interpretive approaches to dealing with complexity is bridged. This enables learning at both individual and team levels and ultimately full use of cognitive, socio-emotional and action-taking capabilities.

ACHIEVING REQUISITE VARIETY: INTEGRATIVE SYSTEMS METHODOLOGY

With *integrative systems methodology* (ISM), a methodological framework has been proposed which explicitly leverages the complementarities of SD and organizational cybernetics for the benefit of actors seeking to achieve requisite variety (as postulated by Ashby's theorem, which is a cornerstone of organizational cybernetics). *Variety* is a technical term for *complexity*. The theorem of requisite variety states, 'Only variety can destroy variety' (Ashby, 1956). It implies that actors must aim at bringing their own repertory of behaviour into balance with the variety of the situation they interact with. This can be achieved by attenuating situational complexity ('foreign variety') and amplifying their own ('eigen'-) variety, by means of cognitive, structural or communicational–interactional adjustments. This applies to actors at any level—individual, team, organizational, etc.

ISM is an heuristic device designed to support this process continually and systematically. The conceptual model of ISM is outlined in Figure 1, and in Figure 2 additional details are delineated. Two of the systemic features of ISM are its circular conception and its multidimensionality. As shown in Figure 1, ISM stresses three dimensions. The first two dimensions are reflected in the two loops on which it is based, namely, a *content loop* and a *context loop* (hence the double arrows).[2] Both of these require different conceptual tools for dealing with complexity. Qualitative and quantitative SD modelling will be recommended for the content level, and VSM modelling for context. The third dimension is process, in the sense of a sequence of operations, expressed by the arrows. The two loops in Figure 1 are separated only for the purpose of analysis. In fact, they are intertwined and in practice often show overlaps. They revolve iteratively, along a set of operations. The number of these operations could vary as a function of the notation. Here, a set of four operations is used—modelling, assessing, designing, and changing—which can be sufficiently well distinguished and specified.

Given the circular structure of the process, one could start anywhere with its description. Also,

[2] This scheme was inspired by earlier works of the cybernetician Raúl Espejo (1993), namely his cybernetic methodology, and the postulate studying content, context and process of change, as formulated by the organization scientist Andrew Pettigrew (1985, p. 50).

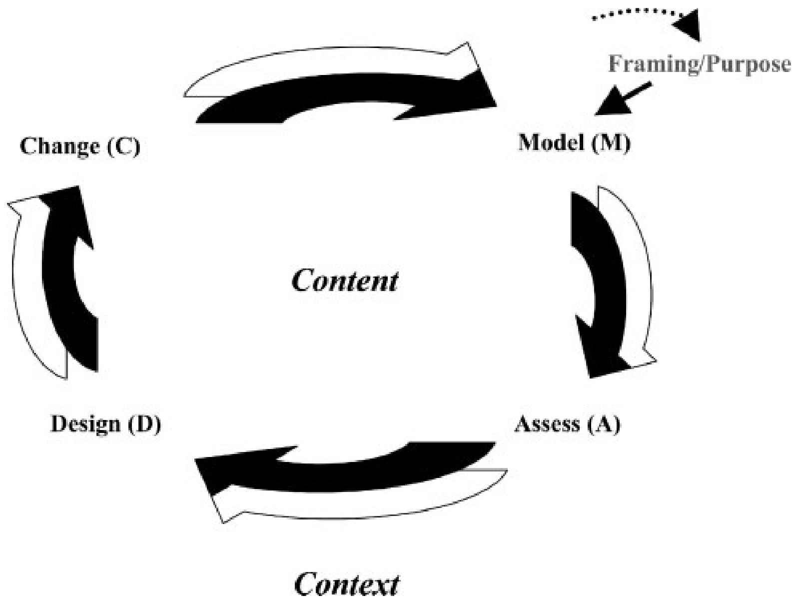

Figure 1. Integrative systems methodology: conceptual model

in practice, the starting-point could be anywhere. Sometimes, actors are suddenly confronted with an assessment or a model from which they have to proceed. We shall take framing as the point to start with, framing being a kind of anchor for sense-making. It concerns the questions regarding the purpose of the process: What is the aim of the process? What is the system-in-focus? Which are the relevant perspectives? These are questions that should be dealt with early on. Modelling then includes tasks such as specifying the goals and the factors critical for attaining those goals, surfacing issues and elaborating models. Assessing comprises tasks such as apprehending the dynamics of the system, simulating and exploring scenarios, and interpreting and evaluating simulation outcomes. Designing includes tasks such as ascertaining

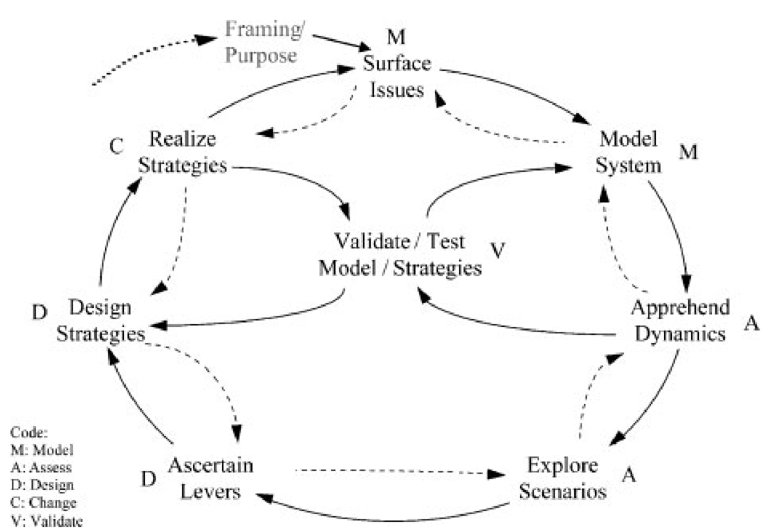

Figure 2. Integrative systems methodology: heuristic outline for handling the content and the context dimensions

control levers, and designing strategies and action programs. Under the term 'change' are included all the tasks that encompass the realization of strategies and action programs. This is about realizing or bringing about change.

The more detailed diagram (Figure 2)[3] gives concrete hints concerning the design of the process. It is applicable at both levels: content and context (as outlined in Figure 1). The sequence outlined is almost self-explanatory but some aspects need to be specified. Firstly, the number of discrete types of activities could also be somewhat increased or decreased. However, the current number seems reasonable: the number of activities presented is large enough to permit making sound distinctions. At the same time it is small enough to allow the process to be handled in a sovereign manner, because the cognitive limitations of actors are taken into account (cf. Miller, 1967).

Secondly, the practice of handling complex matters with the greatest confidence implies a rather more reticular picture of the activities outlined; the simplified diagram, which expounds a sequence, is an abstraction. For example, in a strategy-making process there is often a loop which links the steps of strategy design, exploring scenarios and ascertaining levers, which passes through many iterations.

Thirdly, there are iterations between and within steps, which link qualitative and quantitative modelling and reasoning. For example, in modelling, quantification is always preceded, and often also followed by qualification. Also, not every issue or aspect has to be captured in a quantitative model.

Fourthly, the issue of the quality of models and strategies is of prime importance. Therefore, validation is an activity which is located at the centre of the ISM process diagram. Linked to the chain of activities via two main loops, it is conceived of as a crucial, ongoing endeavour to improve the models and strategies continually. This process of validation must not be confined to an application of a few statistical tests. Validation here includes both qualitative and quantitative procedures; much of it is about surfacing and challenging assumptions. In the context of systemic modelling and design, a whole set of tests, structural and behavioural, theoretical and empirical, needs to be applied in combination. Good introductions to validation techniques are provided by Barlas (1996) and Sterman (2000).

APPLICATION: OVERVIEW AND INTRODUCTION TO CASE STUDY

The practice of management is continually confronted with paradoxes—perceived contradictions which result from the different meanings an event may take on/assume depending on the logical level of observation. A cost reduction can make sense from an operative point of view, because it redeems the current profit and loss statement. At the same time, this very cost reduction might be highly detrimental from a strategic point of view, if it impairs a value potential, for example by necessitating compromises in the quality or innovation domains.

The different meanings ascribed to phenomena are often at the core of dissent and conflict in organizations. Consequently, building models collaboratively is of growing importance in management teams, especially if they find themselves in turbulent environments. In applications reported earlier, such collaborative modelling ventures were undertaken as part of more comprehensive problem-solving or design processes.

Several applications of ISM have been reported in the literature, two of them in a fairly detailed mode (Schwaninger, 1997; Weber and Schwaninger, 2002). I shall take this opportunity to refer to the first case, which has in the meantime been enriched by a follow-up concerning the results achieved. Also, several important aspects can be fleshed out which had to be omitted from the first report (Schwaninger, 1997).

The case in question was a Regional Innovation and Technology Transfer System (RITTS). The RITTS are network organizations promoted and supported by the European Union (EU), and are intended to enhance the global competitiveness

[3]This diagram builds on a scheme of the *Methodology of Network Thinking* developed by Gomez and Probst (Gomez and Probst, 1987; Probst and Gomez, 1992).

of European regions. They are being developed in several regions of Europe. Under the umbrella of a research initiative on Computer Based Modelling, Simulation, and Graphic Representation of Technology Innovation Networks of the EU,[4] the author carried out an action research project to test the usefulness of systemic modelling and simulation approaches. The concrete task was to support the newly formed Steering Committee in Aachen, Germany, in developing the regional innovation and technology transfer system of which it was in charge.

The project consisted of two major modules: the construction of a qualitative model, and the ensuing elaboration of a quantitative model, by means of the SD methodology. The details of the process were documented in two reports submitted to the EU research coordination agency.

In the first module, a qualitative SD approach was used by a group of 19 key actors, plus a handful of assistants, all of whom were involved in the Aachen RITTS. At the same time, other research groups developed similar activities in different European regions (Hamburg, Germany, and Helsinki, Finland). The result was a qualitative network model which provides a rough impression of the variables and parameters representing the Aachen RITTS, as well as their interrelationships. The GAMMA software was used for the purpose of easy representation and documentation, as well as for a classification of the variables and parameters. In the second module, a substantially refined and quantified system dynamics model was built, using the IThink software package. To lead through the process in more detail, we shall now refer to the diagrams in Figure 1 (as to the distinction between content and context loops) and Figure 2 (with reference to the detailed steps outlined).

Framing/Purpose

Beforehand, the local agents had to be convinced that this project could make a contribution to the Aachen RITTS. After initial negotiations, the director of the local institutional hub and coordination unit of the project, AGIT—Aachen Corporation for Innovation and Technology Transfer[5]—agreed to have a joint project realized. The two objectives agreed upon were:

- to elaborate a model for supporting the decisions of the Steering Committee; and
- to create a platform for enabling cooperation between the parties involved in the RITTS project (companies, personalities and institutions).

CASE STUDY, FIRST PART: CONTENT LOOP

The content loop represents the work on the subject matter of the issue in hand. In two workshops with members of the Steering Committee of the RITTS and staff supporting them, a first iteration of the process outlined in Figure 2 was accomplished by constituents of the RITTS, with the author as a facilitator.[6] The modelling in this first iteration was qualitative, while in the second iteration a quantitative model was built.

First Iteration: Qualitative Methodology

Task 1: Surfacing Issues

Participants identified the relevant perspectives, namely: companies, citizens/workforce, districts and city of Aachen, external constituencies (potential allies, etc.), infrastructure, education and research, government of the 'county' of Nordrhein-Westfalen (small business department), the European Union, national governmental institutions and the natural environment. This list of perspectives compiled in the first workshop led to the inclusion of further constituents in the following phase of the project. Furthermore, the goals of each of the perspectives as well as factors crucial for their attainment were identified (Table 1). The list of these key success factors provided an approximation to a first set of variables to be included in the model of the system-in-focus (task 2).

[4]Sprint Project DG XIII/D-4.

[5]Original denomination: Aachener Gesellschaft fr Innovation und Technologie.

[6]Beforehand, a preliminary version of that iteration, which contained only tasks 1, 2, 3 and 8, with a smaller group of people, had been accomplished for testing purposes.

Table 1. Perspectives, goals and critical success factors (extract)

Perspectives	Goals	Success factors
1. Corporations	• Viability and development • Competitive advantage • Profitability	• Organization • Innovation • Adaptation and flexibility • Motivation of entrepreneurs and staff • Cost/revenue • Market position • Vision
2. Citizens	• Secure employment • Income and social services • Self-realization • Autonomy • Professional development and education • Work and leisure • Meaning	• Successful companies • New companies • Business-friendly context
3. . . .	. . .	. . .

Task 2: Modelling the System-in-Focus
Proceeding from task 1, the complex interrelationships which constituted the Aachen RITTS were visualized in a network. Figure 3 shows an intermediate version of that network. All the variables were operationalized by definitions. The variable *successful incorporations*, for example, was defined as the percentage of *new enterprises founded* which survived for at least two years.

Task 3: Apprehending Dynamics
Important reinforcing and balancing loops were identified. Figure 4 shows a self-reinforcing type, which was considered a motor of the RITTS.

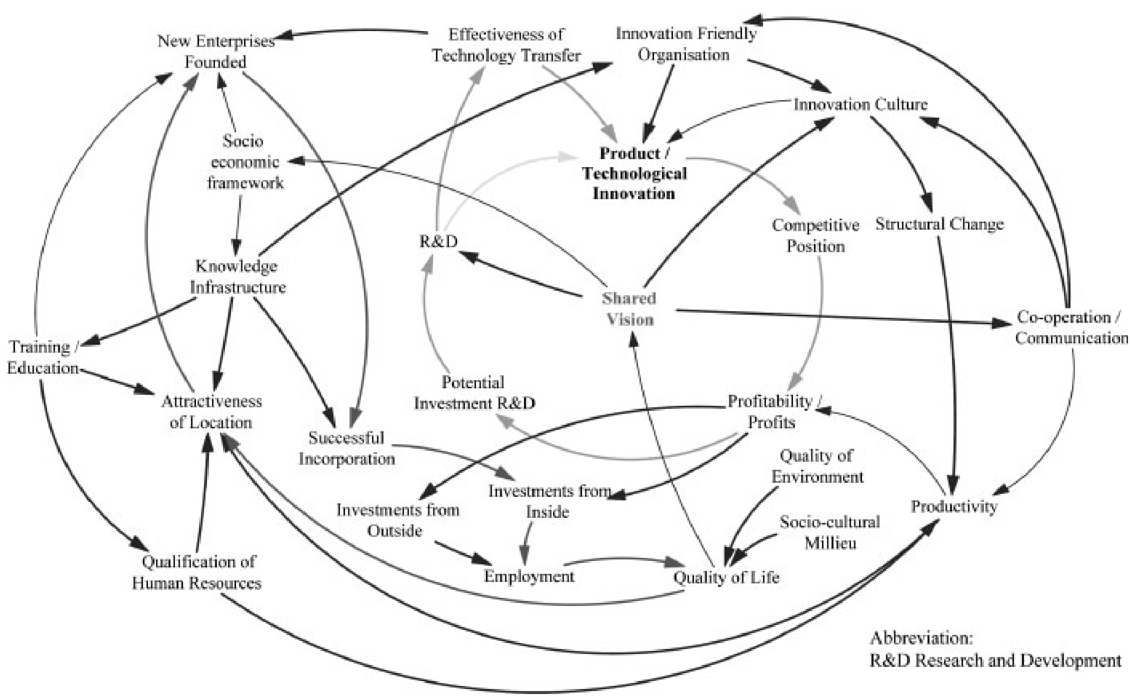

Figure 3. Intermediate version of network (extract)

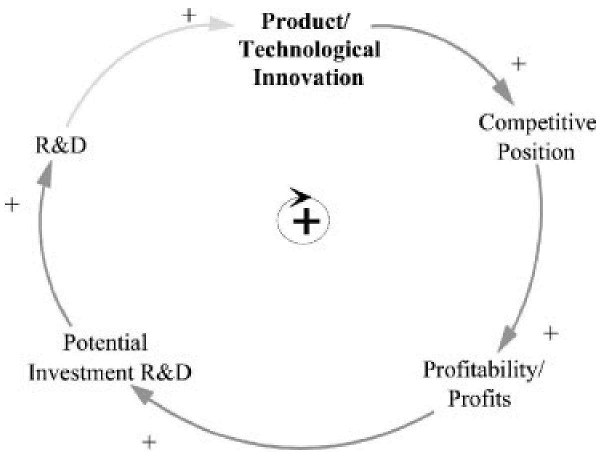

Figure 4. Self-reinforcing loop

Short-, medium- and long-term influences and feedbacks between variables were identified. In addition, the intensities of the interrelationships were roughly quantified (from 3 = strong influence to 0 = no influence). From there, a classification of the variables was undertaken by means of a cross-impact matrix. This can be visualized by a matrix made up of the dimensions of active and passive influence. The four resulting categories of variables are: active—strong influence (high horizontal sum) and weakly influenced (low vertical sum); passive—weak influence and strongly influenced; critical—strong influence and strongly influenced; inert—weak influence and weakly influenced. This categorization is of only subsidiary indicative value.

Task 4: Exploring Scenarios
A systematic construction and exploration of scenarios is usually indicated. In the present case, this step was undertaken only rather informally, owing to time constraints.

Task 5: Ascertaining Levers
Here, a distinction between controllable and non-controllable variables (from the viewpoint of the Steering Committee) was made. Hence, levers of change by means of which strategies and action programs could be built up were sorted out provisionally.

Task 6: Designing Strategies
Based on the improved understanding of the functioning of the RITTS, participants could now set about designing an initial set of strategies and action programs. Also, some commitments for their implementation were negotiated.

Task 7: Realizing Strategies
At the end of the second workshop, the evaluation by participants was very positive. They committed themselves to continuing the initiated work, and to implementing the decisions made in the workshop.

Task 8: Validation
The validation of qualitative models is a problematic and sophisticated matter. In this case, the major validation activities undertaken were an independent construction of models by three groups, followed by a triangulation and consolidation phase; and expert validation by an outside consultant. The latter contributed, for instance, by surfacing and challenging assumptions on theoretical as well as empirical grounds.

By means of these activities, the actors constituting the Aachen RITTS constructed their own models. By discussing their different views, the members of the project developed a shared understanding of the reality they were part of, namely insights into key factors driving the system, levers available to shape the evolution of the RITTS, and strategies to be undertaken. In these workshops, the soft systems methodology proved to be very powerful for the purpose of eliciting knowledge from a heterogeneous group of actors. It led to better mental models of the complex issues under discussion, and to a better understanding by the people involved. 'Better', as used here, refers to a comparison with an earlier state, as well as with a hypothesized situation in which the other methods commonly used in such cases would have been applied.

However, the network-type soft system model could not meet the need for a decision-support model which could allow for quantitative simulations and give well-founded answers to 'What-if' questions. Elaborating such a model was the objective of the project Module II.

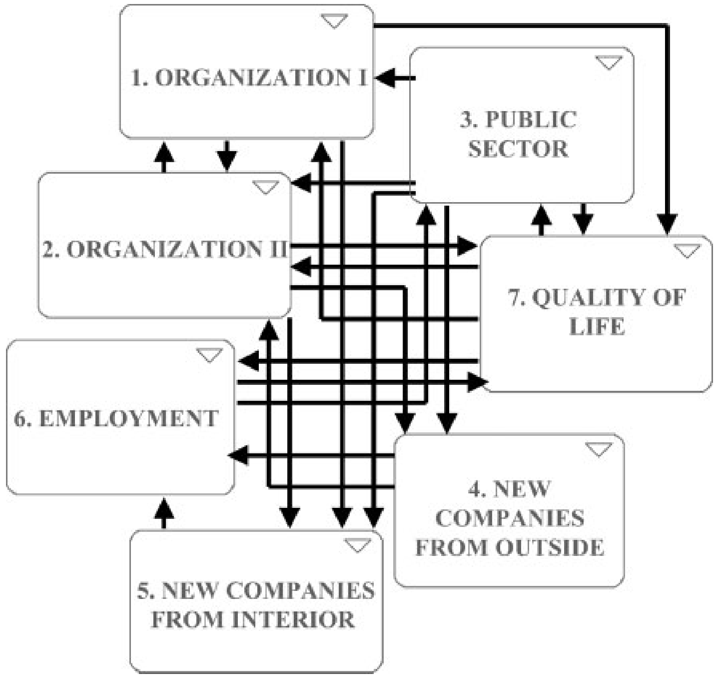

Figure 5. High-level structure of the SD model

Second Iteration: Quantitative Methodology

Subsequently, an SD model was elaborated, together with José Pérez Ríos, a professor at the University of Valladolid, Spain, in the second iteration of the content loop. This led to a model with seven modules: Organization I and II, Public Sector, New Companies from Interior, New Companies from Outside, Employment, and Quality of Life (for more details, see Pérez Ríos and Schwaninger, 1996). Figure 5 shows the high-level map of the SD model. By the end of the project, the model had been structurally validated but not validated with empirical data.[7] Despite its powerful simulation capabilities, this was not a full-fledged decision support model. However, it supported explanations of principle, and (sometimes) gave counterintuitive answers to demanding questions (e.g., How does ecological consciousness impinge on employment in the region? What type of budget allocation will have the greatest impact on regional attractiveness?).

The qualitative network elaborated with the group in Aachen had encompassed only 27 variables, whereas for this one about seven times as many were necessary. Another difference lay in the fact that the second model was, albeit with the agreement of (and with some support from) the local actors, essentially elaborated by two outside observers. Due to resource constraints, the collaboration with local actors was very limited, in this phase. Essentially, the local project coordinator gave some specific hints in an interview with one of the facilitators. For the rest the two SD modellers had to rely on the information and data gathered during and around the two workshops as well as on theoretical studies about innovation networks.

On the other hand, the collective process of working out the qualitative model had induced a sense of ownership in those involved. As more than 20 people had been collaborating in this

[7]In other applications of ISM more extensive validation procedures were realized (e.g., Weber and Schwaninger, 2002).

model-building venture, substantial facilitation skills had been required.

The strengths of the two methodologies applied—MNT and SD—proved to be highly complementary. While relying exclusively on the qualitative model would prove to be insufficient, MNT turned out to be a powerful prerequisite and input for the SD model. Also, the specific procedure followed in the qualitative modelling process led to insights which the traditional, positivistic modelling rationale could not have evoked.

CASE STUDY, SECOND PART: CONTEXT LOOP

The second loop of the methodology concerns the organizational context in which the issue under study is embedded. This part of the ISM process deals with a higher-order aspect. In principle, the nature of the organizational context defines, and delimits, how good or effective a solution at the object level, i.e., at the level of the content of the issue in hand, can be. In the case of the Aachen RITTS project, the best model of the issue-in-focus (representing the functioning of the RITTS) and the best strategies (indicating the orientation of the RITTS) would be of little benefit if the organization impeded their proper implementation.

In principle, the context loop runs through the same sequence of steps as the content loop (Figure 2). I shall not detail each step of the process map but only highlight some core aspects, without differentiating between any iterations.

Task 1: Surfacing Issues
The question of who was in charge of developing the RITTS, and how they operated, was crucial throughout the project. In fact, the organization in question was established very shortly before the start of our project. Therefore, creating a platform and fostering contacts among the parties (companies, personalities and institutions) involved in the Aachen RITTS was an essential objective of our project.

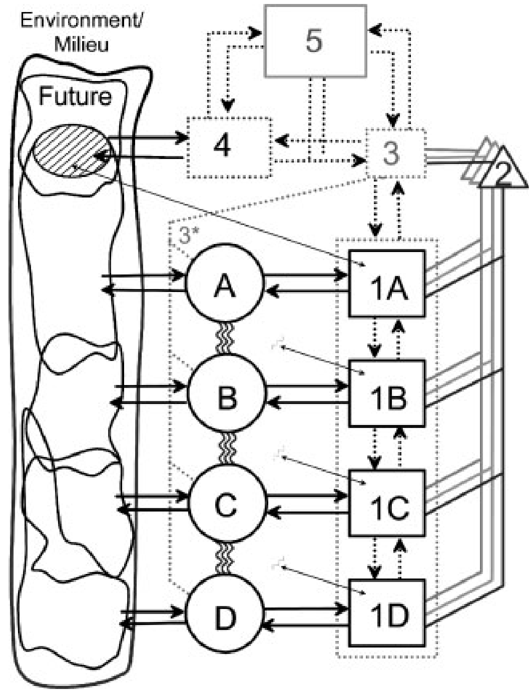

Figure 6. Diagnostic points discerned by means of the VSM[8]

Tasks 2–7: Modelling to Strategies
These steps supported those of the content loop substantially. Only one, but crucial, model used will be mentioned: Stafford Beer's viable systems model (VSM), already outlined above.

Task 2: Modelling
An informal modelling of the structural context in terms of the VSM revealed the following diagnostic points (Figure 6):

- *Normative management*. The Steering Committee clearly had a policy, i.e., a top management function defining the overall identity of the RITTS (System 5 in the language of the VSM), while the group which built models in the workshops described had an intelligence function.
- *Strategic management*. The stature of the function for strategic intelligence and

[8]Diagnosis realized as per 1996. The icons for Systems 3 and 4 are small, given the weaknesses of these functions, as explained in the text.

development (System 4) was still very low at the beginning but grew substantially in the course of the workshops.

- *Operative management*. The RITTS had a strong function for coordination and attenuation of oscillations (System 2) but the overall (operative) management function (System 3) was (still) weak. The links between the overall control function and the primary units (basic units with regulatory capacity (i.e., System 1) and the monitoring/auditing function (System 3*) were ill defined.
- *Basic units*. There was some ambiguity as to the basic units making up the RITTS as a whole but using the political districts, for a start, made good sense.

Task 4: Exploring Scenarios

The base scenario derived from this situation was one where our intervention would probably have little effect.

On a more detailed level, likely outcomes of each phase of the project were simulated on an ongoing basis, in the light of a careful cultural/political analysis, in order to optimize its design.

Task 5: Ascertaining Levers

The external partners of the strategy and development function, given the resource restrictions of the research project, did not have an adequate platform (channel capacity) to transmit their diagnosis satisfactorily to their internal partners.

Tasks 6 and 7: Designing and Realizing Organization-Related Strategies

Consequent upon the above, we, the facilitators, decided to send a report to our internal partners, specifically to the local coordinator of the RITTS project, who is a director of the Society for the Promotion of Innovation and Technology Transfer in Aachen, and call their attention to our diagnostic points.

Task 8: Validation

Essentially, the validation here consisted of a triangulation: the assumptions and propositions of the two facilitators were reciprocally challenged, first by the facilitator who was more 'inside' the project, and then by the one who was more 'outside' in the sense of being involved almost exclusively in the development of the SD model.

The context loop in our case study has not produced a definite result in the sense of an optimal evolution of an organization. Also, the focal organization has shown only limited interest in developing the SD model further and using it properly. However, these are not drawbacks inherent in the methodology itself. After all, ISM emerged only in the course of the case study in hand.

CASE STUDY, THIRD PART: SUMMARY, FOLLOW-UP AND LESSONS

Summary of the Project

This presentation of the RITTS case study has proceeded along the heuristic of ISM as outlined in Figures 1 and 2. After clarification of the goals of the project, a discrete set of steps has been described for both the content loop and then the context loop. At the level of the content loop, in a first iteration a qualitative model was elaborated, and via an assessment (apprehending dynamics, exploring scenarios) an initial set of strategies was designed. In the second iteration, two external facilitators built an SD model. At the level of the context loop, the facilitators modelled the organization under study by means of the viable system model, thereby gaining a number of substantial diagnostic points upon which they acted within their limited range of options.

Follow-Up

One year after the presentation of our final report to the EU research unit (SPRINT) in Luxemburg, the author called the local coordinator of the RITTS project in Aachen for a telephone interview to follow up on the joint exercise. This interview was conducted approximately 21 months after the second workshop. Its purpose was to obtain global feedback concerning the activities developed in the project. At the outset, the interviewer mentioned the two objectives of the project (as outlined above). His interlocutor emphasized that the conceptual work realized in the two workshops had been most effective and valuable for a shared understanding of the issues at hand. Moreover, bringing the multiple actors together 'gave participants the feeling that their cooperation was desired.' They also recognized that their involvement empowered them 'to shape and control things', i.e., the future of the Aachen RITTS. She also pointed out that many of the participants only got to know one another during the second workshops, and that the context of the structured interaction was very favourable, socially and in terms of content: 'We would not have been able to bring such a round of people together in any other way.' Summing up, the joint project was considered a very positive initiation, which the coordinator qualified as 'very, very important'. The cooperation in the context of the new platform had continued. However, making more sophisticated use of the system dynamics model would have required more specialized resources, which were not available at that stage.

Some Lessons

Overall, the somewhat daring attempt to combine the different methodologies was successful. Among the participants, the collective process of working on the issues under study had induced a sense of ownership in those involved. As more than 20 people collaborated in this strategy-making venture, substantial facilitation skills were required.

The ISM framework, which establishes a two-level process—content and context levels—and emphasizes model validation, provided a clear orientation throughout the project. The strengths of the methodologies applied—SD and VSM—proved to be highly complementary.

As far as the modelling at the content level is concerned, the qualitative model turned out to be a powerful prerequisite and input for the quantitative SD model. Also, the specific, participative procedure followed in the qualitative modelling process led to insights which the traditional, positivistic modelling rationale could not have evoked.

The modelling at the context level was a device used by the facilitators to complete the picture. The diagnostic VSM model proved to be highly insightful. It helped to shape their expectations about the probable outcomes of the project and their response towards the organization-in-focus, i.e., to improve the strategy and change process itself.

In further applications of the ISM framework, it would be useful if more space could be provided in order to extend both quantitative SD and VSM modelling in interaction with local actors, to trigger even stronger insights and benefits for the organization.

ACHIEVING METHODOLOGICAL SYNERGIES

At this point the threads of this illustration of ISM by means of the RITTS case study can be brought together in a conceptual respect.

First of all, the complementary capabilities of SD and management cybernetics have been leveraged by combining the two methodologies:

- SD modelling and simulation (a) to approach a complex issue under study, first by means of a rough, qualitative model of the different aspects and their interrelationships, and (b) to deepen understanding of the dynamic complexity of the issue with the help of a quantitative simulation model, to support decision making;
- the VSM (a) to diagnose the organizational context in which the issue is embedded, and (b) to support the design of the structural prerequisites for the organizational viability of the system under study (in this case the RITTS Aachen).

Each of the two methodologies 'solves' a problem the other is unsuited to dealing with; therefore, this case has yielded an instance of genuine complementarity.

The conceptual bridge between SD and management cybernetics—the VSM in particular—was established with the *Model of Systemic*

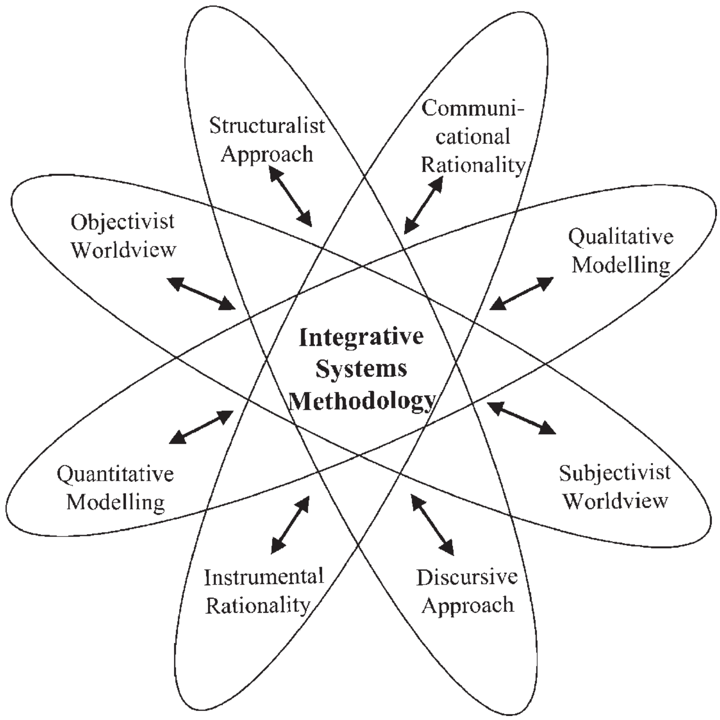

Figure 7. Complementarities framework

Control (MSC), a theoretical model introduced in earlier publications of the author (Schwaninger, 2000, 2001). This model identifies rather abstract parameters and control variables (or levers for change) for the three logical levels represented in the VSM: operative, strategic and normative management. The model establishes the pre-control relationships between these three logical levels and shows the difference between control and pre-control. If the operations are controlled for variables such as quality, profit and the like, these variables are pre-controlled by strategic parameters such as critical success factors and core competencies, etc. Whereas SD is a methodology which makes more concrete modelling and simulation of these parameters and variables possible, the VSM is a device to embody the controls of the different levels organizationally.

The second connection to be made is achieved by means of a conceptual scheme called the complementarities framework (Figure 7).

From the perspective on the two traditions of systemic problem solving given at the outset—the positivistic and the interpretivist streams of inquiry—a series of polarities emerges. These are depicted in Figure 7. Bringing the polarities together in one framework may even appear paradoxical:[9] how, for example, can one reconcile the objectivist worldview with a subjectivist one? A paradox is a set of two apparently contradictory propositions which seem incommensurable to an observer. The diagram shows four pairs of polar opposites. These, however, are also complementary, and it is complementarity which should be stressed here. The four polar categories on the left-hand side of the diagram are more closely linked to the positivistic paradigm, those on the right to the interpretive paradigm.

Over the years, the author has facilitated many processes dealing with complex issues in organizations of all kinds. Very much stimulated by these experiences, a methodology has evolved

[9]This framework has also been called *Paradoxes Framework* (Schwaninger, 1997) and *Polarities Framework* (Schwaninger, 2003).

which appears to offer a higher level of action potential to those who apply it.[10] This methodology is grounded in a dissolution of the four paradoxes in the framework exposed here. The complementarities between the opposites are leveraged as follows:

- Objectivist and subjectivist worldviews are reconciled: all agents who collaborate bring in their subjective views. However, objectivity is sought/maintained in the sense that the models on which the organization in question is to operate reflect the shared views of those involved. In this sense, the emerging models are observer-invariant: the modelling and design process strives for a solid, fact-based 'common ground', i.e., objectification.[11]
- Instrumental and communicational rationalities are both equally relevant: this is reflected in the two purposes of the case study. On the one hand, a better model for supporting the decisions of the steering committee was to be achieved. On the other, a platform for the recurrent communication among the actors involved, about their shared issues, was to be created.
- Qualitative and quantitative modelling are synthesized, whereby a proven approach is to start with qualitative diagrams (in the case of SD with feedback diagrams or stock-and-flow diagrams) and then to continue by building up quantitative simulations models.
- Structuralist and discursive approaches are combined: this dimension is very closely linked to the dimensions of the rationalities but adds a nuance. The structuralist–functionalist approach to modelling and design, linked to the instrumental dimension, is complemented: the ongoing discourse in which arguments and concerns about diagnostic, design and action-related issues are exchanged opens up a space of communication beyond the realm of proofs and refutations. Opportunities for experimentation and innovation are provided.

[10]This type of inductive reasoning is similar to grounded theory building as conceived by Glaser and Strauss (1967).

[11]See Rapoport (1953) on the concepts of objectivity and subjectivity as used in operational philosophy, and his definition of 'objectivity' quoted above.

The point of this systemic heuristic is to combine and balance the opposites in all four dimensions. This should enable coping with complexity more effectively, because the focal actors can thereby acquire a richer repertory of potential modes of behaviour, i.e., higher, and possibly requisite, variety. First, the heuristic obliges them to deal with the issues in hand not only at the content level but also at the level of their organizational context. Secondly it impels them to overcome the paradoxes outlined, formerly widely considered to be insoluble. The curved lines around the pairs of polar opposites in the Complementarities Framework are meant to hold them together (like rubber bands, to use a simile) through a (meta-)methodology, ISM.

STRENGTHS AND LIMITATIONS OF ISM

The case study reported here illustrates the strengths of ISM. First, it is based on a synthesis of:

- the subjectivist framework, with different actors designing their own models, and the objectivist framework with the quest for a best possible (consensual) model representing a domain of reality shared by a group of actors;
- the instrumental rationality in the quest for valid, logically sound, robust models and designs, with the communicational rationality of a group striving to cope with situational complexity;
- the qualitative modelling capturing multiple perspectives in a few highly aggregated, fuzzy variables with quantitative modelling, which calls for additional formalization, analysis and desegregation;
- the structuralist approach concerned with identifying the logic of functional structures and relationships, and the discursive–procedural approach, which investigates the negotiation of shared mental models, mutual interests, and the generation of new ideas.

This synthesis is possible only because the poles of the framework, which appeared to be antagonistic, are in fact not mutually exclusive but *complementary aspects of methodology* necessary for dealing with complex realities.

Secondly, and related to these aspects, a specific strength of ISM lies in the simultaneous operation of the process at the *content* as well as at the *context* levels. Churchman argued that an inquiring system designed for valid insights must undergo 'complexification'—in Ashby's terms, must attain 'requisite variety'. In complex social systems, a viable paradigm of inquiry which observes Ashby's law can only be grounded in distributed problem-solving, activating all members of the system in a virtuous mode. To put it in a nutshell, this must be based on dealing with non-trivial issues on two levels: content and context. According to ISM, actors representing the environment of the relevant issue or problem are to participate in the problem-solving process. This appears to open up new paths towards better solutions, and a more effective realization of strategies and action programs at the same time. Also, the combination of the positivistic and the interpretative modes adds richness and depth to the concept of requisite variety.

As Churchman stated, however, it is impossible to exclude the indeterminate and the non-explicit from an inquiring system. Yet ISM reveals a way to design a context in which actors can enhance their requisite variety to deal with indeterminacy more effectively. Bringing together the holders of different and even contradictory views and interests in a constructive discourse, supported by jointly formed and espoused models, can lead to the uncovering of hidden assumptions and the patterning of a joint activity—the lack of which might entail events being perceived as random or surprising.

Thirdly, ISM shows a path to a coherent combination of methods and even methodologies which is much superior to merely eclectic approaches.

On the other hand, ISM is not free of limitations. This can be illustrated by means of a comparison with a range of methodologies which have similar aims:

- In comparison with general methodologies of action, e.g., praxiology (Kotarbinski, 1965) and the so-called science of design (Simon, 1981; Gasparski, 1984), ISM gives fewer general principles for action, and its philosophical basis has been less elaborated upon.
- Although democratic participation is a principle inherent in ISM, questions of power and emancipation have not been treated here. These are a main concern of other methodologies, namely critical systems theory and heuristics (cf. Jackson, 2000; Ulrich, 1996).
- Compared to system methodologies such as soft systems methodology and total systems intervention, not as many concrete examples of ISM applications have been documented in scientific publications (cf. Checkland and Scholes, 1991; Flood, 1995).
- In comparison with methodologies which focus on the modelling of problem solving in social systems (e.g., Mesarovic and Takahara, 1985; Klir and Elias, 2002) those furnish a formal apparatus which ISM in itself cannot offer. In contrast, ISM provides a heuristic by which different methods are combined, with its focus—for the time being—on a synthesis of the methodologies of qualitative and quantitative SD, and organizational cybernetics.

OUTLOOK

Over the years, SD research and practice have evolved from their essentially positivist roots towards an inclusion of the 'rationalities' inherent in the interpretivist and constructivist paradigms in their epistemology. SD modelling and simulation were actually conceived from the beginning as an approach to enable human actors to shape the realities they (and their clients) had to deal with (see, for example, Forrester, 1961, 1968). This orientation has been maintained throughout and is growing ever more pronounced (e.g. Meadows *et al*., 1972, 1992; Richardson, 1996; Sterman, 2000). Moreover, initiatives to reframe SD in terms of interpretivism (Lane and Oliva, 1998), social constructivism (Vennix, 1996) and integrationism (Lane, 2001) have been taken. Similarly, management cybernetics has come from a positivist tradition. However, it has assimilated interpretivist and constructivist influences in the sense of giving human actors in organizations devices to conceptualize and reorganize the contexts in which they operate (cf. Harnden, 1989; Espejo *et al.*, 1996).

The ISM presented here continues in this tradition. ISM manifests a number of features:

- It transforms several polarities into complementarities, e.g., by combining qualitative and quantitative modelling.
- It tries to achieve a synthesis of the positivist tradition with the constructivist framework, or at least to reconcile these two approaches.
- It requires careful modelling of both the substantive issue at hand ('content loop') and the organizational context in which it is embedded ('context loop').
- It requires thorough model validation, an aspect widely neglected in the realm of qualitative modelling and even considered irrelevant in much of the interpretivist tradition.

It opens up new perspectives, including a fertile synergy of SD and organizational cybernetics, for the purpose of dealing with complexity more effectively.

This is not the only way of harnessing complementarities of systems methodologies, nor is this paper written to proselytize disciples for one specific methodological approach. It is merely meant to be a contribution to the evolution of the methodologies by which complex issues in organizations and society can be dealt with in systemic ways.

Summing up, it can be seen that ISM provides a framework with the potential to help actors to deal with complex issues more effectively. Therefore, it also seems reasonable to conclude that ISM can support processes to enhance organizational fitness and intelligence. Future research should assess whether the claim holds that ISM leads to progress in the quest for requisite variety of organizational actors, and if that claim is true, why this might be the case.

As demonstrated here, ISM has up to now made use of the formal modelling tools of quantitative and qualitative SD, and the VSM. Future research should examine whether it makes sense to combine other methodologies, and what the implications would be.

Also, a more extensive study should examine the philosophical underpinnings of ISM: namely, its roots in the philosophy of applied science; the methodological and technical principles to be made explicit in technological instructions for the use of ISM; the limits to combining methodologies, e.g., due to paradigm incommensurability; potential complementarities or synergies other than those elaborated here; and the practical ability of individual actors to work with different methods or methodologies from different paradigms.

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