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(Re-)Structuration of System Dynamics[1]

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System dynamics, as a methodology of structure and behaviour, can play a significant role in theory building in the social sciences if it can bridge the language barrier between systems approaches and the main stream of social theory. To most social scientists, the true concept of system dynamics remains hidden within its computer simulation apprenticeship. Lane (2001) rightfully demanded to engage with the main streams of social theory to overcome this unsatisfying situation. In this paper, the theory of structuration is suggested as an appropriate ontological background, providing a sociological access to the core concepts of system dynamics. In return, system dynamics is thought to hold much promise for structuration theory in aiding reflexive control and system reproduction. An emphasis is laid on qualitative system dynamics, the concept of mental models, and the connections between the system dynamics and structurationist nomenclature.

Keywords: theory of structuration, system dynamics methodology, mental models, qualitative system dynamics, learning

> Methodologies must have a theory underlying the knowledge that they claim to impart, and that theory must be understood because it constitutes the crucial self-defining assumptions of a discipline, its perspectives (or even its blinkers). (Lane 1994: 110)

0. Introduction

For some time, system dynamics has been regarded as theoretically weak, from inside the discipline as well as from outsiders (e.g. Flood and Jackson 1991; Lane 1994; Richardson 1994). Part of this weakness stems from its isolation from the rest of the social sciences and their theoretical discussions. Up until Lane (2001) no reference was made towards the growing momentum of structuration theories in the social sciences

[1] Much credit has to be given to Ms Julia Walther M.A. who's assistance in editing this paper improved the author's appreciation of the English language as regards grammar, punctuation and paragraph structure. Whatever remains still inappropriate falls solely into the author's responsibility.

(Bourdieau 1982/1990; Giddens 1981/1984), which has immediately provoked fruitful discourse amongst social theorists (Habermas 1984; Callinicos 1985; Kießling 1988; Walgenbach 1995). Lanes (2001: 302 et seqq.) "new suggestions for the system dynamics method" conclude with assigning the system dynamics community four tasks: (1) better communication with the rest of the social sciences through clarification of system dynamicists' language; (2) engage into critical discussion with social theorists about the nature of the method; (3) learning from, but avoiding, pure subjectivism; (4) development of an integrative grounding, reflecting on the 'duality of structure'. Undoubtedly, all of this taken together is most likely the greatest endeavour system dynamics has faced since the founding of the discipline, surpassing Richardson (1994) in his bid for research in problem fields "for the future of system dynamics".

Lane (2001: 306) ends his paper in firmly answering 'yes' to the question, whether the agency/structure debate holds, despite of its theoretical difficulties, an opportunity for system dynamics. This paper accepts the tasks set, but approaches them slightly different. The endeavour undertaken will venture on another route and emphasis than Lane projected. Neither is the paradigm-based analysis rejected, nor is simulation regarded as system dynamics' true 'coronation', all efforts have to lead to. To re-structurate system dynamics resembles a detective's task, starting with closely looking at and thinking about 'obvious' proof and circumstances, while slowly progressing to a 'knitting together' of already interwoven strings. This, of course, can just be a rough outline, which needs further rigorous discussion. Nevertheless, as Giddens stated, if ideas are interesting and enlightening, their origin does not matter, as long as they bear the option of honing them in critical reflection (Giddens 1997: 35). Therefore, this paper will

- First look at the social sciences, with an emphasis on their 'nature' as a science and the special problems connected to it, including the so-called dualism of subjectivism and objectivism. This will clarify some essential theoretical claims on a (social) systems approach.
- Then some notes on systems thinking are necessary – with strong reference to system dynamics, its ontology and a close look at its epistemological base. Thus it will be able to understand the implications of Lane's (2001) tasks for system dynamics as a scientific theory.[2]
- After that, the 'locales' of system dynamics is triangulated within the framework provided by Burrel and Morgan (1979).[3] The 'movement' of system dynamics – or maybe its true position all the time – within this framework will prepare the ground to revisit some of its core concepts.
- These core concepts, namely the dependency on structure and the underlying feedback loops, will then be connected with the theory of structuration and its nomenclature.

[2] If system dynamics is or should become a "science in its own rights", appears to be a strongly debated question within the system dynamics community. Nevertheless, even if system dynamics is or remains 'just' a suitable method for solving problems by providing a structural language and certain mathematical methods, its underlying ontology and epistemology need to be clear, or in other words, system dynamics cannot "operate without any rule book." (Lane 1994: 122)

[3] Which the author of this paper, despite Lane's (2001: 305 et seq.) conclusion that this might not be useful, still holds as a valuable and necessary reference frame.

- ❖ In the end, hopefully, a possible outline and prospect of system dynamics within a new social paradigm, and concretisation of the tasks assigned by Lane (2001) will be sketched.

1. Theory in the social sciences

> It was assumed that empiricism applied to the facts of social life would yield generalizations and predictions on the pattern of natural science. This has not yet happened, and though a century is not a long time in the history of an idea, it does appear that the hiatus in the substantive development of the social sciences is due to the special kind of difficulties they face. (Checkland 1999: 67)

These difficulties appear to be rooted in complexity of subject matter. The interconnectedness of problems in social systems puts a limit to reduction necessary for "meaningful controlled experiment". One possible approach to this problem is the search for patterns in social life, which obviously do exist.[4] Expectations we have about the behaviour of others are, at least in general, matched by the observed behaviour. In sociological terms this is known as "double contingency" (Luhmann 1984: 149 et seqq.) which is built through "rationalisation of action" (Giddens 1997: 54 et seqq.) Generally, social sciences of all kind are concerned with the understanding and explanation of social action, with an emphasis on its controlling mechanisms (Weber 1972). The nature of these explanations is of a very distinct kind compared to their counterparts in the natural sciences. Theory in the natural sciences is, in a way, isolated from its research object. Although e.g. quantum theory tells of the dependence between research object and spectator, the object itself is not affected by theory. In the social sciences, on the contrary, there is always a feedback between the explanans and the explanandum. Theory, therefore, has a "transformative influence" and becomes part of the research object, which contains older theories (Giddens 1997: 31 et seqq.). These older theories, unlike their 'natural' siblings, do not "die on our behalf", as Karl Popper once said (Popper 1984: 126). They remain part of the research object and influence new theories. Another 'problem' in the social sciences is the 'contextuality' of social behaviour (Giddens 1984: i.e. 28, 176; similar Checkland 1999: 70). Any social actor – be it the individual, a group or an organisation – responds according to the contexts of a specific (external) problem situation as well as its own (internal) contexts.[5] With Checkland one can rightfully argue that

> This kind of argument suggests that at best social systems will reveal 'trends' rather than 'laws' and that the social scientist will be reduced to studying not exactly social reality but only the logic of [*contextual*] situations… And over the years, with growth of human knowledge, the

[4] Discovering and describing behavioural patterns in social systems is at the very heart of the system dynamics method as outlined in this paper. In fact, in the history of system dynamics this has always been a big issue, i.e. with the search for system archetypes (Senge 1990).

[5] 'External' would be the situational and institutional factors 'around' the actor, whereas emotional and cognitive factors are 'internal'. Therefore, the same actor would act differently in different external contexts, whereas a different actor in the same external context but with different internal contexts would react differently. For the distinction between external and internal contexts see Kals and Montada (2001).

> 'logic of situations' -- which will involve actors' contribution of meaning -- will gradually change. (Checkland 1999: 71)

The previous remarks make it clear that any statement in the social sciences can hardly be anything law-like[6]: the explanans (theory) *always* changes the explanandum (practice). The social sciences, therefore, participate in constituting their world in a way natural sciences don't. Theory, then, is best not viewed as discovering invariant laws, but reflecting on the cognitive process itself, which will be of interest later when dealing with mental models and their elicitation (Bayer and Stölting 1994: 303). Although law-like statements are not possible, others are. Statements based on norms and rules, heuristic methods and principles, hypotheses and experimental assumptions are the foundation of theory building in the social sciences (Esser 1993: 82 et seqq.).

Another 'specialty' in the social sciences is the conflict between 'two tribes': objectivism and subjectivism.[7] This conflict transcends all varieties, all 'clans', within these paradigms, including system dynamics. The existence of the two tribes reflects the dualism of 'individual' vs. 'society' in social sciences: is it the individual human actor or the institutional settings that determine individual and collective behaviour? Methodological individualism, being the core concept of the subjectivist tribe, emphasises the reality of the individual: only through analysing action and behaviour of human individuals, social phenomena can be understood. All statements about these phenomena can be traced back to the descriptions of individuals without loss of meaning. 'Laws' in social sciences exist only insofar as they refer to the psychological dispositions of individuals. The totem of the objectivist tribe on the other hand, can be described, more or less, in one word: structure. It is the structure that restrains and guides all behaviour (Parsons 1971). The individual human being and its motivation is not an interesting object of research. 'Objective', from a structuralist point of view, are only parameters which can be explained without reference to an individual predicate. A structuralist, therefore, tends to eliminate the individual into a greater whole, for the sake – and reality – of the system.[8] In *Figure 1* this distinction is detailed in two axes: horizontally objectivist-subjectivist, vertically examining the scope between society as a self-regulating system and society as change-driven[9].

To recall the main focus of this brief description:

- Any approach, including system dynamics if it wants to be of relevance in the social sciences needs to consider the reality of the individual as well as the reality of institutional (or structural) constraints.

[6] A law, as a prerequisite, must describe univocally definable cause-and-effect relationships, which can be validated without dependence on location, time or the researcher as well as other research contexts.

[7] References to this dualism are numerous. In philosophy it can be traced back to the "eidos" of Plato ("real" ideas, an objective being of things; world II) vs. Protagoras and his "man is the measure of all things". David Hume took on the subjectivist position with his "Treatise of Human Nature". In the cognitive sciences, interestingly, this dualism is resembled within the mind-body-problem. For an in-depth reference see Popper and Eccles (1977).

[8] In fact, Luhman's seminal work "Soziale Systeme. Grundriss einer allgemeinen Theorie" starts with the declarative statement, that systems do exist -- as ontological entities, and not just in the eye of the observer.

[9] Figures are to be found at the very end of this paper. As stated earlier, this is the Burrel and Morgan framework (1979) and their classification of sociological paradigms. For a more detailed explanation of the four paradigms and their implication for systems approaches see Lane (1994: 111-113).

- ❖ It has to be kept in mind that theory constitutes practice and cannot clearly be separated from the latter. Theory, therefore, cannot be a set of universal statements but has to resemble a heuristic method with specific concepts and principles.[10]
- ❖ A special emphasis has to be laid on the cognitive process itself.

2. Theory behind reality: ontology and epistemology in systems thinking and system dynamics

> [S]ystems thinking is the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure. (Richmond 1994: 139)

Systems thinking, in general, is something of a meta-theory, an ontology of how the world can be looked at and described.[11] Checkland argues that systems thinking can be seen as a reaction to failure of the scientific method of the natural sciences to solve complex problems in social systems (Checkland 1999). Richmond (1994) develops a system dynamics 'label' for systems thinking: structural thinking, combined with (experimental) learning (137). The word "systems" in the term systems approaches points to a certain view on real-world problems that is holding the interactive framework of a complex whole responsible for ill behaviour instead of individual actions of parts. A 'systemist', therefore, prefers holism to reductionism. Holism lays emphasis on the whole rather than the parts or even the (individual) sum of the parts. From this stems the systems thinker's belief that a complex problem can only be understood through examination of the interaction of parts and their interconnectedness rather than looking at the parts themselves. Although a good antidote against reductionism, the 'whole before parts' dogma opens the door for structuralism and the tendency to 'eliminate' the subject.[12] Maybe the best description of systems thinking is the following: a way of looking at and naming real-world problems from a holistic point of view (Jackson 2000: 18). Within the greater field of systems thinking, system dynamics is but one method, although, practitioners recognize it as an integrative theory of complex systems (Lane and Smart 1996: 87). In fact, system dynamics is seen by its founding father as an interdisciplinary language providing for many sciences, especially the social sciences (Forrester 1971: viii). Such a language, which has been described elsewhere as an 'ideal language', can help formalise everyday and respectively natural language, thus making inferences in the social sciences accessible to scientific investigation (Radnitzky 1994: 401).

[10] The contextuality of all social processes is also of some significance for the role of the modeller (or 'expert'), who cannot be thought independent from her research object.

[11] A meta-theory is focussed on central real-world phenomena and is distinct from empirical theories (e.g. contingency theory, theory of evolution) and epistemological theories (e.g. critical rationalism, constructivism).

[12] Lane (1994: 117) refers to this problem in the context of the wide-spread use of the term systems thinking in the field of system dynamics: "The employment of this term to describe our own single methodology is virtually to deny the existence of any other. If we use that term for our own discipline, we are putting ourselves in a mental prison."

All systems approaches are model-based due to lack of possibility (and often morality) of real-world experiments. Thus, modelling science is often at the heart of the systems thinking 'Weltanschauung', expressed in the concept of 'mental models' or 'cognitive maps', which play the dominant role in the first phase of model building (Randers 1980: 118). Models, therefore,

> are understood not as true, solvable, objective representations of parts of the real world (ontology-based). They are accepted as subjective intellectual constructs (epistemology-based), explanatory devices that can be used to explore and understand parts of the real world. (Lane 1994: 105)

The primary model purpose is to help people involved in model building learn about their problems and to generate meaning.[13] Known as early as 1957, the term 'mental model' has its firm stand within the systems ontology (McKellar 1957). When mental models are picked as a central theme, they often come in close relation to learning and are described as rationalised images of knowledge, which are subject to permanent learning processes (Krieg 1971: 81). Individuals construct mental models as well as 'wholes' or groups of actors, the models of the latter being referred to as "internal models" (Weber et al. 2000). The existence of mental models is explained with their effect on reducing complexity by providing general patterns and schemes of behaviour, comprised of vast and detailed knowledge (Bleicher 1972: 271). The existence of internal (system-wide) mental models lays ground for the emergence of cooperative structures as well as behaviour. Internal mental models, therefore, work as a 'social glue' of any system (Albert and Silvermann 1984: 13). Given the fact that any approach in the social sciences has to look very closely at the process of cognition, the construction as well as elicitation of mental models will be of interest when dealing with the concept of reflexive control later in this paper.

As stated before, the metaphorical power of systems thinking, especially in system dynamics, is indeed its greatest contribution to a wide range of research fields, from business administration to economics, sociology and psychology, providing an ontology for describing central phenomena of social reality. If system dynamics wants to be a science in its own rights, some clarifications about its underlying theories are necessary. Even more so, because of the "significant confusion" between ontology and epistemology[14], which could not be clarified within system dynamics up to the present day (Checkland 1999). *Figure 2* sharpens the theoretical locales of system dynamics among a classification of theory types. As can bee seen, on the ontological level system

[13] This is quite similar to a lot of the functions of mental models described elsewhere in this paper. The subjectivist domain, unsurprisingly, having in mind its epistemological background, appears to lay a heavy emphasis on processes of meaning construction.

[14] The main difference between ontology and epistemology is the different emphasis as regards to existing objects ("things") and their properties. From an ontological point of view, it is asked if properties have an independent existence apart from the things which exhibit them (i.e. Barney is lazy. Is "laziness" independent of "Barney", or, in other words, can there be a description of "laziness" without reference to "Barney"?). An epistemological question would be how properties of objects are observable through a cognitive process. The key interest of an ontologist on the other hand, is to categorise "actualities" into a list of "simple" categories that cannot be further reduced. Such ontological categories are objects, properties, structure, relations, sets, numbers, and actualities (Grossmann 2003: 71 et seqq.). Such a list of categories is scientifically helpful to reduce complexity within a discipline, group and relate its concepts and make them accessible to research. System dynamics describes and explains the relations between individual behaviour, structure and policies, providing a formal (structural) language.

dynamics is portrayed as partly identical to systems thinking. Not all concepts common to systems thinking are shared by or are of substantial importance to system dynamics (i.e. autopoiesis or self-organisation).[15] It is ontologically challenging, yet not impossible, to change or widen the underlying meta-theory of system dynamics with the theory of structuration. One great benefit from this 'widening of the base' is to avoid the dualism also seen within the range of systems approaches in systems thinking (Jackson 2000).

The movement of system dynamics in the past, which will be of interest in the next chapter, as well as its possible future headings, leave also an impact on the epistemological base of the discipline. A long discussion it has been, what underlying epistemology system dynamics follows. A contender for quite some time was critical rationalism (Bell and Bell 1980). From this point of view, critical rationalists believe in an objective truth and a single scientific method of approaching this truth: through a logic of conjectures and refutations. Despite its significant success in the natural sciences, for the social sciences this epistemology holds some difficulties, the image of *one* subject-less truth being the most problematic.[16] Another problem is the "death" of falsified theories. In the natural sciences, these theories are devalued and only of interest to a historian. In the social sciences, however, theory constitutes practice and therefore makes an irreversible impact on its research subject. Even if a social theory is falsified (e.g. the historical materialism of Marx, done very convincingly by Popper himself in his "Open society"), it remains within the body of social knowledge and influences future theories (Giddens 1997: 48 et seq.). Therefore, the epistemological position of critical rationalism cannot be a safe standpoint for system dynamics.

Turning towards constructivism, it is argued that

> A system is first of all a way of looking at the world… The system -- its identity, parts, and relationships -- cannot be anything else but a construct or distinction by an observer; and different observers in different contexts and with different purposes may make different distinctions… We are languaging it [*the system*] into existence. (Espejo 1994: 202)

Central to a constructivist epistemology are processes of self-reference and self-organisation. Reality is not thought possible, at least not in a meaningful way, without an observer, who can never take the part of the "impartial spectator":

> According to this view, reality is an interactive conception because observer and observed are a mutually dependent couple… Objectivity is a subject's delusion that observing can be done without him. Invoking objectivity is abrogating responsibility, hence its popularity. (Heinz von Foerster, as cited in the Declaration of the American Society for Cybernetics 1985: 5 et seq.)

Constructivism stems from forceful thought-out realism and executes the theory of autopoietic cognitive systems. Individual human beings are not limited by their 'inability' to capture the real world without the use of models or systems of descriptions. It is the human mind itself that constructs meaning within this modelled reality. Meaning in this context is not something foreign to, but inside human beings

[15] Richmond (1994) locates system dynamics within systems thinking. In this paper, the notion is that system dynamics is *partly* a subset of systems thinking with the possibility to lean into and incorporate other ontological frameworks.

[16] In defence of Popper it has to be added that it was not in his intent to establish a single scientific method, but a pluralist approach to epistemology, firmly based, of course, in the belief of an objective reality (Popper 1984).

and, in fact, of their own making (Rusch 1985: 212 et seqq.). Most fertile for system dynamics is the emphasis of constructivism on closed cognitive systems: the way a system perceives its environment is depending on its internal cognitive apparatus and the schemes laid out in it (Paslack 1991: 165). This resembles most strongly the concept of mental models, which has been identified as central to system dynamics. Problematic in constructivism is its tendency to practise epistemology without ontology, thus eliminating the Cartesian doubt. This would, indeed, point to a new form of objectivism, which is eager to get rid of the cognitive subject it has placed in the centre of its campaign against realism (Glaserfeld 1987: 411).

Vázquez et al. (1996) have proposed another epistemological base for system dynamics with Putnam's internal realism (i.e. Putnam 1981 and 1983). Internal realism also puts strong emphasis on the concepts of mental models. In the light of internal realism there is no reality, at least no problem-specific useful reality, outside or independent of conceptual schemes. This epistemology is similar to critical rationalism in its rejection of realism ("metaphysical", as Putnam calls it) and, for instance, the non-rejection of objective truth.[17] It is completely different in rejecting the *usefulness* of an objective (i.e. context-less) truth. Most closely, it relates to constructivism in its internalisation of objectivity into the cognitive systems of the observer. For system dynamics, internal realism means that there is nothing relevant "outside" our mental models. They are, in fact, the conceptual schemes and therefore epistemic elements. These epistemic elements

> link with reality the archetypes or generic structures that are the basic representational elements of SD "language". (Vázquez et al. 1996: 33)

For that reason, system dynamics models are the main vehicles of knowledge and insights; they become, as elicited mental models, epistemic elements. In the light of internal realism, the

> selection of the SD models with the most realistic content must be made by experts and users and has a crucial justification in relation to the structural dependence and sensibility that some real systems have on the human actions developed in them. (ibid.)

This still holds the danger of 'expertism' and gives way for a model-building elite, as elicited expert models become mental models of users. An internal realist would counter this argument by stating that all models are contextual and if an expert wants to "sell" her model, she would have to take into account the context of the later user. As Putnam argued, the common sense world is not separable from science and vice versa. The most valuable contribution of an epistemology of internal realism to an epistemological foundation of system dynamics, is the notion that underlying real-world structures are in fact guided by the generic structures embedded in our mental models and show some kind of reverse constitutive relation, which will be described later when dealing with the concept of duality of structure. Furthermore, the quality of system dynamics as an interdisciplinary language is emphasized and reaffirmed.

It has become clear that an epistemological grounding for system dynamics has to be built around the centrality of mental models as cognitive schemes or structures. thus focussing on the cognitive process itself. Mental models can never be subject-less or

[17] It has to be added that Putnam views critical rationalism also somewhat metaphysical, when aiming at its belief in objective truth as a sort of "holy grail" to be approached.

context-less, because human individuals organise their knowledge in and through them (Sterman 1994: 294). It has to take into account the subjectivity of the observer who is not only embedded in her social context, but also in her research object. The individuality of observer and research object constitutes social theory as well as social reality.[18] Cognitive processes, within closed cognitive systems, are at the heart of a system dynamics epistemology laying heavy emphasis on (1) how, through mental models, real-world systems are perceived and structurated into generic structures, (2) how to elicit these internalised structures which influence behaviour, (3) how, with regard to the duality of structure, behaviour constitutes real-world systems, according to mental models. In brief, what is needed is a theory of cognition and learning, which explains processes of internalisation, elicitation, and institutionalisation of knowledge (Berger and Luckmann 1995).

3. The 'locales' of system dynamics: movements and pavements

> Attaching oneself to a single method only, especially if the underlying assumptions of that method are not clear and apparent, is a dangerous enterprise. (Lane 1994: 119)

From the outside, system dynamics has always been accused of being the computer-aided execution of rigid functionalism (Ansoff and Slevin 1968) and is more correctly spelled social systems theory with a software package (Lane 2001: 303). This perception has been reinforced, at least accidentally, from the side of system dynamicists, with numerous quantification efforts in building world models, while at the same time disregarding the discipline's weak theoretical standing (Lane 1994: 122) as well as a certain ignorance by social theorists towards a seemingly theory-less 'engineering' method. Despite this, Lane (1994) sees system dynamics in a tradition with 'softer' systems approaches, in trying to implement the idea of learning processes, locating the discipline within a radical humanist setting. He believes "that this is the appropriate underlying paradigm for system dynamics when used to promote learning." (122 et seq.)

Vázquez et al. (1996: 27) are also claiming that the purpose of system dynamics models is not to predict and control, but to explain and understand. This is not only pointing to a less functionalist, more subjectivist stance of system dynamics, but it also abandons the purpose of 'design for control', at least as it has been carried as a banner of the discipline from its early foundations (Forrester 1961: 45). Not to be unfair to the founding father of system dynamics, Forrester (1972) himself gives early reference to learning, and connects it to his concept of structure. It is through the adaptation and transformation of common patterns of structure ('generic structures') into diverse problem areas, that learning is excelled. Learning, therefore, is above all the learning and understanding of structures, as well as their 'structuration' into generic structures and general patterns ('structural knowledge'). These steps help ensuring the adaptability of learned knowledge, which in turn is subject to permanent testing and changing, in

[18] There is no 'impartiality', only scientific (in fact: Cartesian!) scepticism.

other words: learning (12). Furthermore, the issue of model validation, as crucial for system dynamics as for any model-based science, has always been viewed as only thinkable with proper reference to specific problem context (Forrester 1968b: 616). Pointing in a similar direction, it has been stated, that system dynamics "is, relatively speaking, vulnerable to subjective influences" (Legasto 1980: 32). With learning as the central means and ends of system dynamics, the method is moving from its adherence to regulation to describing and enabling social change. This movement, although maybe not in its broad impacts, is also recognized within the system dynamics community (Richardson 1996: 141).

An interesting move towards – or maybe better, acknowledgement of – subjectivity, is the field of qualitative system dynamics. Despite the emphasis in early (and most of contemporary) system dynamics on the development of quantitative models, it has been stated "that there could be value simply in rigorous approaches to system description" including qualitative modelling; furthermore, "describing a system is, in itself, a useful thing to do and may lead to better understanding of the problem in question." (Coyle 2000, 225) One of the problems, the tendency of quantitative models to get way too complex for the uninitiated (and, frankly speaking, often for those mastering the field as well), has given reason to call for further research how to make models accessible (Richardson 1996: 147). Another problem are the cases of "compounding uncertainty" (i.e. embedded in non-linear functions). Where the correspondence of model variables and the real-world system is lacking the required soundness, "one should, perhaps, restrict the analysis to the qualitative level, which … was useful in this instance, rather than producing a model that is of no value." (Coyle 2000: 233) Other limitations of quantitative modelling are the dimensional inconsistencies between real-world entities and model variables. Qualitative modelling would also counteract the tendency of people, owed to the rise of sophisticated modelling software tools, "equating the discipline with a particular package." (357) In this regard, the use of multipliers in system dynamics models is seen as a source of risk for double counting and compounding uncertainties:

> If the uncertainties combine and compound in such ways, it may be hard to believe that dynamics of the model *and the policy inferences made from it*, are more 'correct' than can be achieved from a qualitative model. (228)

The uncertainties mentioned are not just something more computational power or precise parameter estimation could tackle; in fact, they are inevitably inherent in all quantitative modelling approaches. The boundary quantification should not go beyond is set by

- Uncertainties concerning the relation between model and real-world variables, including non-linearities and dimensional (in)consistencies;
- Divergent objectives of model clients/stakeholders;
- Conflict between model clients/stakeholders (237).

Qualitative system dynamics could well yield an answer to these problems, and it has been also stated that the "relations between these qualitative practices and the quantitative core of the field of system dynamics are unclear." (Richardson 1996: 149) It is one attempt of this paper to show that the "core of the field of system dynamics" is not quantitative modelling but much more essential than that: its structural, feedback-

driven view of reality. At the heart of qualitative system dynamics is the construction of several diagrams of different aggregate levels for different purposes, which has proven popular with clients (Coyle 1998: 351 et seqq.). A consistent visualisation technique is recommended. Interestingly, the suggested influence diagrams used in this qualitative approach to system dynamics are not merely a sketch of some causal-loops; in fact they are of a stock-flow-type and therefore structural, avoiding the limitations of causal-loop diagrams (Richardson 1986). A system dynamics modelling endeavour is, in the light of these findings, threefold (Coyle 2000: 241):

- Visual system description by using structural diagrams (distinction between state and flow variables, and their feedback connection).
- Critical study and checking for suitability of the visual description.
- Decision for quantification according to the stated boundaries.

It has become clear that system dynamics is, and probably was right from the start, unlike any functionalist approach of 'hard' systems thinking. Even more, it is unlike any interpretative approach and might never turn 'soft' (Lane 2000). Clearly, system dynamics, as triangulated in this paper, is neither subjectivist nor objectivist; it is above and beyond all… structural. Therefore, the notion of 'structural thinking' given by Richmond (1994) can act as a guiding light detecting the 'locales' of system dynamics in the in-between of the subjective-objective divide.

4. Crossing the ditches of social theory: structuration and reflexive control

> All human action is carried on by knowledgeable agents who both construct the social world through their action, but yet whose action is also conditioned and constrained by the very world of their creation. (Giddens 1981: 54).

Structuration theory is based on the premise that the dualism between objectivism and subjectivism has to be reconstructed as a *duality of structure*: structure as a constraint *and* enabler of social action, a medium *and* result of practice. Although recognizing the significance of the linguistic turn, it is not a version of hermeneutics or interpretive sociology. While acknowledging that society is not the creation of individual subjects, it is distant from any conception of structural sociology. Duality of structure denotes the reciprocal constituency of structure and behaviour. Therefore, "the structural properties of social systems are both medium and outcome of the practices they recursively organise." (Giddens 1984: 25) The duality of structure and its implications are at the heart of any structuration theory: (1) no such things as society or social systems are thinkable without individual human beings, (2) individuals do not create but reproduce and change social systems according to the institutional framework or, as Giddens calls it, its structural properties (Giddens 1997: 224). The theory of structuration attempts the 'structuralist decentration' of the subject without its elimination from theory: a third way between determinism and voluntarism. It is, more or less explicit, an attempt "to allow the actors to free themselves from oppression and domination" (Bertilsson 1984:

343). Structuration, therefore, is not Parsonian structuralism where parameters are regarded as objective when being without reference to an individual predicate (Giddens 1997: 267). This is clearly impossible in any social setting. Although structuration theory sees no society without individual human beings, it is also very different from methodological individualism, which reduces all social phenomena to the individual level (270 et seqq.). It is through routines, laid down in structure, that structure is reproduced through everyday behaviour.

The very phrase of *structuration*, borrowed from the same French term, characterises a social process of structuring and thus reproducing social systems by conscious actors,

- recurring on rules and resources embedded in the very same social structures, which are constituting as well as being a product of social action;
- monitoring their actions as well as the actions of others
- in which working theories about intentions and outcomes of behaviour are employed and tested ('rationalised')

in which learning occurs and leads to better working theories which are the basis for building social routines, providing for system stability.Briefly, structuration refers to the conditions governing the continuity or sustainability of structures and therefore the reproduction of social systems (Phipps 2001: 189).

Structure, in Giddens sense, is a property of social systems, their rules, resources and transformation relations (Giddens 1997: 77 et seqq.). Structure in the theory of structuration consists of rules and resources:

- *Interpretative rules* constitute meaning, thus enabling communication.
- *Normative rules* sanction behaviour and legitimise goals.
- *Allocative resources* are control over physical capital.
- *Authoritative resources* are control over people, organisations, and the organizing process itself.

These rules and resources are interdependent and are described in the theory of structuration as different dimensions of structure (83 et seq.):

- *Signification* denotes symbolic ordering and coding ('constitution of communication').
- *Legitimisation* denotes regulative ordering ('constitution of norms').
- *Dominance* denotes political / economical ordering ('constitution of power')

These structural dimensions are not sharply distinct: dominance is shaping symbolic ordering, while at the same time depends on legitimisation, which in turn is constituted trough interpretations of political and economic resources. All of the dimension are thus mutually dependent and can only be separated for methodological reasons. Despite the 'solid' appearance of rules and resources, structure has no existence independent from the knowledge of conscious actors (79). Structure exists only as memory traces, the organic basis of human awareness of social rules ('knowledgeability'), and is reproduced through rule-guided action. Structure therefore contains reproduced actors' knowledge (laid down in rules and resources), while on the same hand affects actors'

behaviour (through 'sedimented' rules providing for social routines). Structures are at best 'virtual' and only 'instantiated in action' among conscious individuals.[19] Through this structure-guided behaviour, structure and its properties are in itself reproduced.

A *system*, on the other hand, is a 'virtual' object which is realised in practice through routine interactions of its actors in time and space. These routine interactions, their repetitive character, are the material foundations of social practice, the ongoing constitution of structure. The most enduring and regular practices are referred to as institutions. To identify systems and institutions, one has to look at the realised practices themselves. While looking at the realisation of practices, the 'system is attributed to these realisation processes *ex post*, i.e. systems exist as generic entities in the way that these very practices could not be carried out without them. Therefore, the outcome of a system is an outcome of the systemic interactions as a whole, not the outcome of a single individual member (Yanow 2000: 248). In a very elegant way, this as-if-view avoids the 'fallacy of reification', the pitfall in attributing the system a 'sui generis' existence *ex ante* like most of hard systems approaches tend to.[20]

Structuration theory, at least as described by Giddens, seldom gives reference to a concept of knowledge, apart from structure as reproduced actors' knowledge. The emphasis is laid on *consciousness*, which is distinguished from unconsciousness, the latter being no object for direct actor influence (Giddens 1997: 35; see also Bordieu 1990: 140). Conscious actors inherit a 'reflexive capability' of knowing, what they do, why they do it, and how to do it best while doing it. The knowledge about actions and underlying assumptions, the actors' 'knowledgeability' is present within what Giddens calls 'practical consciousness'. This is a sort of 'taken for granted' knowledge, thus non-discursive. It is the sediment knowledge of social contexts, conventions and traditions and, therefore, the prerequisite for and result of social routines, which aid the process of sedimentation through repetitive interaction. Within practical consciousness, the 'memory traces' of structural properties manifest themselves and become action guiding without the need for active reflection (Giddens 1997: 36). Embedded within this practical or sediment knowledge is the discursive consciousness or knowledge. Discursive knowledge is obtained by *reflexive control* of behaviour (Giddens 1984: 25, 60 et seqq.). Intentions behind behaviour patterns and routines are made explicit and subject to critical reflection in the light of incoming knowledge. Actors 'theorise' and routinely develop a theoretical knowledge about what they do, how they do it, and why they do it. This 'rationalisation of actions' is an explication of intentions and their association with certain possible implementations. Reflexivity, therefore, is a way of exerting control over social systems. Discursive knowledge, then, is knowledge that has been tested and evaluated, thus assuring that knowledge about social processes remains adaptable, while at the same time enables actors to control these very processes.[21] A

[19] Structure occurs only through time. For the temporal character of structure see Barley and Tolbert 1997: 100. It must be acknowledged that structure does have the ability to 'accumulate', especially within allocative resources, but also in 'textual' rules. Still, resources need to be interpreted as resources by conscious individuals in a given context. The same accounts for rules. Otherwise, there would be no churches and no declaration of human rights, only bricks and letters on paper.

[20] It also provides a more 'realist' view on systems than most of soft systems approaches hold. The system is not 'just' languaged into existence by an observer; moreover it is realised by this observer in interaction with others. A structurationist view therefore has implications beyond its ontological scope.

[21] Indeed, in this paper the terms 'consciousness' and 'knowledge' will be used synonymously, although a distinction has to be made between consciousness as knowledge (output of a learning process), and consciousness as the learning process itself.

'stylised' setup for reflexive control within the process of structuration would resemble the following steps:

- Routines (practical knowledge) realised in interactive social practices.
- Reflexive monitoring: periodical control of action to establish (enforce) internal and external conformity
- Rationalisation of action: production of codifiable hypotheses resp. inferences about social action (discursive knowledge).[22]
- Repeated application of rationalised interpretative patterns.
- 'Sedimentation' and/or 'codification' of discursive knowledge in social routines (practical knowledge) and/or rules and resources.

An interesting reference in Giddens (1997: 79, 245 et seqq.) is the *reproduction circuit*: institutionalised relations of structural properties controlled either by homeostatic causal loops or reflexive (self-) control. Reproduction circuits, or reproduction loops, are responsible for sustaining as well as changing social systems by the means of *duality of structure*. Giddens uses the term 'duality' instead of dualism to distinguish his theory of structuration from other ontological meta-theories in the social sciences. The theory of structuration is neither subjectivist nor objectivist; it spans across the sociological 'ditch' and is both one and the other. The duality of structure is usually described in comparing the afore mentioned dimensions of structure – signification, legitimisation, dominance –with their interaction – counterparts communication, sanction and power – linked by the transformative 'modalities': the analytical 'locales' between structure and behaviour. Modalities are properties of structure, the interpretative rules, norms, and facilities (resources).[23]

Through the duality of structure, structural properties let alone are not sufficient for system reproduction; structure inherits no knowledge independent of the individual actors. With each other, in so-called co-presence, they execute reflexive control and therefore reproduce the systems structure. *Figure 3* tries to capture the essence of the structuration process:

- Individual actors (inter)act under co-presence and awareness (practical conscience or knowledge) of social rules.
- In interaction, resources (allocative and authoritative) are used within power relations; actors are building and testing hypotheses about each other's actions, and therefore rationalising their actions (reflexive control).

[22] "Ordinary life is possible by ontological security, which is based on the routinization of actions and is made to happen by the actors' reflexive monitoring of their actions." Fuchs 2003: 141.

[23] The coin metaphor Giddens employs does not refer too well to the recursive character of structure and behaviour. It might be easier to think of the duality of structure as two sides of a strip of paper. When this strip is bent and twisted and put together at the ends, a topological form emerges which is known as 'Möbius strip': a two-dimensional form, twisted in the third dimension, a strip with only one side. Structure and behaviour then lie on a continuum of the same side of the duality of structure, the 'locales' where the constitution of social reality takes place. When beginning with structure as sediment actor's knowledge, one follows its path in becoming attached to and attaching rules and resources, which are instantiated in routine-guided interactions of conscious individuals. Moving along the behavioural 'realm' of the strip, processes of reflexive control and learning are taking place, with the outcome being discursive, thus codifiable knowledge, that can be made textual in the 'rulebooks' or sedimented into social routines, either way changing and reproducing structure and its properties.

- In executing reflexive control, actors learn about their "theories in use", the social rules, power relations and so on.
- Through repetition of this discursive knowledge, explicated in rationalised actions, routines are developed which reproduce as well as change social rules, and become practical knowledge ("memory traces", in structure reproduced actors knowledge).

Therefore, it is through the process and circumstances of reflexive control, change and stability in social systems are reproduced.[24] To conclude, the main thoughts of the theory of structuration in summary are:

- Individual actors are subjects acting consciously. The (discursive) consciousness through repetitive routines is embedded in the practical conscience. The idea of (hu)man, the guiding action model is that of 'homo conscius'.[25]
- Human consciousness is always bounded. Boundaries are set by the unconscious, unacknowledged conditions and unintended consequences.
- Routines are the dominating mode of social activities. Routines provide actors with self-awareness.
- Structure and behaviour are reciprocal. Individual actors use structural properties to reproduce these structures (Giddens 1997: 335 et seqq.).

Although the theory of structuration appears to hold certain promises, some statements of Giddens accompanying certain parts of it, need clarification. The first clarification might look a bit trivial, but is nonetheless central to this paper: it is regarding the role of structure. Giddens, for most of the time, positions his arguments strongly against the *structuralist* paradigm, although structure plays a central role in his theory of *structuration*. His roll back of structuralist positions has to be seen in the light of their sheer dominance in social sciences since World War II. Structure, in the theory of structuration, is a positive term providing individuals with resources and power necessary to exert control over their everyday lives. Through the duality of structure, social practices are memorised, reproduced and reinforced in and through the institutional framework of society.

The second clarification is provoked by his rejection and, moreover, deconstruction of evolutionary – or as he put it: evolutionist – approaches in the social sciences. Giddens challenges, very convincingly, the evolutionist idea of a deterministic 'antrorse' development of society. This would mean, that the present configuration (of society, organisations and so on) is the best and only practicable under present circumstances. The problem Giddens is pointing at is well visible: evolutionist approaches tend to view certain processes and developments as universal. Another problem is the reliance of evolutionist approaches on an adaptive mechanism at work. Giddens clearly negates the existence of such mechanism, stating that there is no possible reduction to something like adaptation because of the contextuality of social action. This evokes some criticism. Giddens' rejection of determination and a certain 'fixed' direction of social change are, without a doubt, to be backed. But these are, for anyone who is familiar with darwinist and neo-darwinist concepts, not evolutionary at

[24] In a term used earlier: socially 'glued' together.
[25] This is the authors 'brainchild' of the conscious human, in opposition to the 'homo oeconomicus' of the methodological individualists, as well as the 'homo n.n.' of the structuralist provenience.

all.[26] Evolution is not determined ex ante. It just looks *as if* ex post. Evolutionary developments are not reversible, at least not like rewinding a tape. Successful adaptation can only be interpreted as "successful" after the adapted feature has been positively selected. The future is the blind spot of evolution. It is through contingency (variation) and necessity (selection) that change is driven. A truly evolutionary approach would take this into account, just as the theory of structuration lays an emphasis on unintended consequences.[27] Through them, variation takes place and feeds back to the individual as well as the collective actors.

Another clarification needs the explicit rejection of an adaptation. Giddens denies the possibility of intrinsic motivation, clearly avoiding the methodological individualists' trap, but thereby kindly ignoring his own creation, reflexive control. Through the individual's reflexivity, action is rationalised and control over complex social systems is exerted. A simple mechanism like adaptation, might be not the proper candidate for a causal mechanism controlling and driving social change. Reflexive control appears to be a much better suited contender. [28] It is indeed the belief of this author that the concept of reflexive control is at the heart of an evolutionary theory of social change.[29]

The last clarification is a reply to criticism, aiming at a seeming inconsistency between duality of structure and reflexive control (Mouzelis 1989, Baguely 2003). In brief, it is argued that

> The concept of self-reflexivity necessitates a theoretical recognition of the splitting of "subject" and "object" that Giddens rules out of order with the notion of duality of structure (Baguely 2003: 136).

This critique refers to reflexivity being an individual concept based on individual action. In fact, it is true insofar as the theory of structuration as advocated by Giddens, knows no collective actor like organisations. The main thrust of criticism centres on the act of reflexive control, when individual actors have to 'separate' themselves from structural constraints to reflect on and change them, *as if* they were not, as Giddens so heavily

[26] For probably the best and mostly well readable insights from a linguistic point of view on Darwinism and Neo-darwinism see Dennet (1996).

[27] Unintended consequences are indeed a fundamental driver of change and a main object of interest in social research, as Giddens points out.

[28] Giddens himself states very precisely that continuity of social practices implies reflexivity, which in turn is only possible due to continuity of social practices. Reflexivity reproduces these practices identically through space and time. Reflexivity is a permanent feature of human individuals. Through reflexivity, routines are solidified (practical consciousness!) which then guide action. This on-going process resembles an infinite regress or *durée*, as Giddens calls it: a stream of reflection, building routines and action. It is clear that continuity depends heavily on the practical (non-discursive and therefore non-reflexive) consciousness. The sediment knowledge of the practical consciousness is a necessary condition for the viability of individual as well as collective actors; reflexivity, in addition, is the sufficient condition for a sustainable viability. Therefore, reflexivity appears to be a positively selected feature of human evolution.

[29] Giddens speaks of 'coincidences' being responsible for social change. In the author's humble opinion, that these coincidences are (a) variations of intentional (reflexive) actions ("unintended consequences"), and (b) adaptive as well as anticipative behaviour due to learning processes. They are responsible for the necessary flexibility and viability of social systems. The theory of structuration therefore inherits an evolutionary moment. What has to be admitted, is the base unit of social change is still missing. In biology, there is a clear set-up of gene – individual – population/species. The gene is the base unit of biological evolution, where variation is taking place; individuals are selected; populations/species evolve. Maybe mental models can be the 'social' counterpart.

emphasised, two sides of the same coin but distinct from each other (144).[30] It would expand the scope and aim of this paper to refute this critique as thoroughly as would be required to do so. The claim of these authors to reintroduce a methodological as well as ontological dualism can be rejected, when the seeming "temporal non-correspondence of structure and agency" (149) is viewed from a cognitive perspective: actors do not reflect context-less, nor is their thinking in neither way separable from their cognitive processes and structures. Duality of structure is, indeed, consistent on the level of individual and collective cognition: cognitive structures constitute the very ways of the reflection process whereas the results of this process reproduce as well as change the cognitive structures. This points to the urgent need of an evolutionary based structuration theory, wherein duality of structure is reproduced "bottom-up". In brief, what is needed to refute this critique, is a theory of cognition as foundation of the before mentioned theory of social change. Given that cognition and reflection involve learning, the contribution of system dynamics to the theory of structuration starts to become clearer.

This was, indeed, a very brief round up of central aspects of the theory of structuration. The attentive reader will have noticed some of the interwoven strings to which system dynamics could be tied. A structurationist approach in the social sciences matches the remarks made in chapter one, regarding mainly the reality of the individual as well as its societal surrounding, and the reciprocal constitution of theory (structure) and practice (action). It further provides an adequate ontological background needed to categorise and deal with complex social phenomena, taken into account the contextuality and subjectivity of social action. Also, some of the structurationist agenda seems in line with the remarks about an epistemological grounding of system dynamics. The former will be discussed in the following chapter, when key concepts of system dynamics are re-visited and their possible use within the theory of structuration are discussed. The latter will merge into the final chapter about future prospects (and research tasks) of a structurationist view on system dynamics.

5. Radical structuration: system dynamics… re-visited

> The heart of system dynamics is the feedback structure. Its basic components are a level (or stock), a rate (flow), and a connecting loop. System dynamics advocates assert the generality of feedback structures in social systems -- that no real decision or policy can be made outside a feedback structure. (Legasto 1980: 36)

System dynamics has always been, at least in its self-perception, a philosophy of structure in systems, i.e. relating structure to behaviour (Forrester 1968a: 406). Any system's behaviour is solely relying on its internal structure, its state and the given decision policies. Externalities are regarded as shocks to which the system reacts according to its internal arrangements (89). The hierarchy of structure in system dynamics is as follows (Forrester 1968a: 406 et seqq.; Forrester 1972: 87):

[30] In this context, the 'as if' argument is an important one. Methodological 'bracketing' of object and subject is not a real-world phenomenon. The real world does not 'freeze'. It is within the cognitive process this bracketing seams to appear.

- System boundary (internal behaviour before external shocks)
- Closed feedback loops (basic element of any system)
- State variables (system states, stocks, levels, anything that accumulates)
- Flow variables (decision rules, policies, routines, rates, flows)

The interwoven character of structure and behaviour is emphasised, even though the dependence seems to run just one-way, from structure to behaviour. The emphasis on structure dependency in system dynamics is persistent, also with authors who share a more constructivist viewpoint (Espejo 1996: 206). In brief, structure in system dynamics resembles a way of formally describing real-world problems with the emphasis on problem solving. It is perfectly in line with what Gibbons et al. (1994) have labelled as Mode 2 research:

> Knowledge production carried out in the context of application and marked by its: transdisciplinary; heterogeneity; organizational heterarchy and transience; social accountability and reflexivity; and quality control which emphasizes context- and use-dependence. (167)

With Richmond (1994) it has been argued, that system dynamics is first of all about structural thinking. There is more to this statement than it might seem at first glance. Richmond is very explicit about the relation between structure and behaviour, though not connecting it in the way a 'structurationist' would:

> Structurally, systems thinkers see both the generic and the specific, not just the latter. Behaviourally, they see both patterns and the event, not just the latter. (140)

A 'structurationist' would add: systems thinkers see structure and action as different aspects of the duality of structure, woven together in a reciprocal constituency of system reproduction. However, one major shortcoming of system dynamics ontology must be clear: it focuses on feedback loops and aggregated quantities. There are no processes and no interactions of conscious actors (see *Figure 4*). A restructurated system dynamics would have to lay a heavy emphasis on realisation processes as well as actors and their rules and resources. One possible way to achieve this could be to put actors in the loops of causal loop diagrams (Liddell and Powel 2004). Interestingly, this could yield an easier access to the question, where the dominant loops are: it could be the loop with the dominant (rules and resources) actor. Another way to focus on processes lies in putting these very processes at the centre of the modelling tool itself (LeFèvre 2004).[31] Any which way will have to give clear reference of conscious actors and their potential to skilfully realise decision policies (and to change those policies).

As stated earlier, reflexive control appears to play the central part in reproducing and sustaining social systems. Two aspects within reflexive control are apparent and seem to bear a good 'knitting point' as to the restructuration of system dynamics: knowledge (practical and discursive) and learning. From a system dynamics point of view, three kinds of knowledge can be described (Vázquez et al. 1996: 24):

- Structural knowledge (generic structures; patterns; system archetypes)

[31] This would be despite the author's (Cartesian) scepticism towards software tool(ing)s.

- ❖ Quantitative knowledge (empirical knowledge, time series, statistics, data sheets, "the books")
- ❖ Operational knowledge (practical knowledge, skills in combining (1) and (2))

Within this scope of knowledge, an interesting reference is made to the reliability of structural knowledge that mental models provide about certain systems. The reason for this lies within the systems themselves, which are claimed to be "the result of human actions guided by these same mental models." (25) This is a strong reference to the duality of structure, which is matched by a remark from Espejo (1994) when he argues:

> Organizations are constituted by people's moment-to-moment interactions in their operational domains. It is through these interactions that relationships are formed, and in a given space and time, the organizational structures supporting people's actions are formed. (201)

If it were not system dynamics, one would likely be able to hear the structurationist argument that all structure resembles reproduced actors' knowledge *laid down in mental models*. Mental models are, in effect, the interpretative schemes Giddens speaks of, which are used to 'routinise' interaction (Giddens 1997: 82). In system dynamics, generic structures, canonised system models and system archetypes provide rationalised images of knowledge, which act as masters for mental models. Mental Models, therefore, are truly epistemic elements, carrying something 'realised' as well as the potential to realise, helping to ensure system adaptability and sustainability. The elicitation of these mental models can be equated with the first step of structuration, the rationalisation of action. A restructurated system dynamics would shift the emphasis from simulation to elicitation and thus the cognitive process itself.

Clearly, a successful elicitation method has to fit the purpose of the discipline with its way of thinking and model building, just as well as the way people naturally think and 'theorise' each other's actions, thus executing reflexive control. From the perspective of behavioural psychology it has been argued that mapping techniques like scripts, schemas, and stories are at least a sound first step (Doyle 1997: 259). A second step certainly has to adopt a more visual, diagrammatic form like hexagons, causal loops or, preferably, structural diagrams. This fits in quite well with an elicitation method proposed by Ford and Sterman (1998), although it is primarily aimed at tracking expert knowledge for estimating parameters, initial conditions and behaviour relationships.[32] Its appropriateness for qualitative mapping comes clear when learning in and about (mental, as well as verbal and formal) models, is viewed as learning about structure. Ford and Sterman (1998: 310) appear to have the same view on the issue, when stating that much "information about system structure and decision processes resides in the mental models of process participants, where it remains tacit." Even more, to the pleasant surprise of qualitative modellers, they

> hypothesize that pushing experts to describe relationships at the simulation model level helps them to clarify and specify their knowledge more than they would if we worked at a more

[32] Especially the second phase (description) makes use of different mapping techniques: visual description in the mind of the expert to focus on the specific relationship; verbal description, using unstructured notes; textual description, where the mental model is moulded into a narrative form, focusing on 'anchor points'; graphic description of the specific relationship. It is clear that the techniques used in this fourfold description phase can be combined (if they are not already identical) with mapping techniques from behavioural psychology.

> abstract level using tools such as causal loop diagrams… We believe that this is true even if *no formal model* is ever built… (Ford and Sterman 1980: 313 et seq.; emphasis by the author)

Such elicitation efforts are allegedly slow and this is, by all means, desirable. Only in an adequately paced elicitation process, "thereby providing more time for reflection and revision" (Ford and Sterman 1998: 331), mental models can be brought to light. For that matter, an important concept regarding mental models is the memory which contains these models. It has been argued, the claim of system dynamics to "increase knowledge retention by providing an organising framework is well grounded in psychology, and there is some empirical support that diagrams designed to help learners build conceptual models of systems aid learning." (Doyle 1997: 285) From the findings of this paper, the diagrams portrayed in this chapter as well as in chapter three, regarding qualitative system dynamics, seem well suited for this task. Outputs of this first step of structuration, then, are 'structural narratives' from which canonised models, generic structures as well as system archetypes – in other words: structural (discursive) knowledge – can be deduced.

Learning constitutes the second step in the structuration process. Learning, the implicit process and result of reflexive control, has long been regarded as the most important benefit from system dynamics models (e.g. Forrester 1972; Senge 1990; Lane 1994; Richardson 1996; Ford and Sterman 1998). Senge (1990) went further when proclaiming that not formal system dynamics models themselves would yield learning, but abstracted system archetypes in which distinctive modes of behaviour are laid down. As noted earlier, Coyle (1998, 2000) is pointing into a similar direction, although much more firmly routed in rigorous structural thinking. Learning takes place (system dynamics) with reflecting on explicated mental models and their underlying assumptions, if possible accompanied by quantitative simulation; learning also takes place (structuration) within the execution of reflexive control through rationalisation of action under co-presence. Here, very clearly, the 'stitch' can be made: through the use of elicitation methods and qualitative mapping, practical knowledge about structural properties as well as presumed actor's behaviour can be explicated and made subject of "theorising". Where applicable, quantitative simulation can be used for testing these hypotheses. Thus, rationalisation of action as well as routine building is enhanced and practical (implicit) knowledge made accessible for discourse.

The third step of structuration is codification and/or sedimentation of discursive into practical knowledge, which changes the underlying mental models or memory traces within structure. Structural narratives transform into the 'social glue' through repetitive use of 'rationalised images of knowledge', thus building and transforming social routines. The codification can take places in the form of moulding reflected structural narratives into abstracted canonised models of behaviour. System dynamics, as an 'organising framework' and 'philosophy of structure', appears to provide an adequate structural language to aid such learning and sedimentation – in one word: structuration – processes, thus aiding system reproduction.

With these steps, system reproduction is ensured and adaptability of social systems, whether towards sustaining or changing structural properties, guaranteed. The process of structuration using system dynamics can well be an outline for system dynamics consultations in general. A restructurated system dynamics modelling and consultation process could then be summarised as follows:

- ❖ Knowledge elicitation through qualitative mapping: *mapping for structuration*
  Through a process of visualisation, verbalisation, narration, and structuration, structural narratives of a complex system on different aggregate levels are told.
- ❖ Critical reflection: *reflecting on structuration*
  Within the execution of reflexive control, the narrated relations, polarities, objectives and conflicts are discursively examined, providing discursive knowledge. Decisions are taken either to model or to map further.
- ❖ Knowledge institutionalisation: *routine-building for system reproduction*
  From elicited discursive knowledge, generic patterns and structures are deduced. By helping to build routines, system reproduction in either stability or change is ensured.

Group model building quite resembles the mapping stage, where the 'modeller' is more or less a facilitator (Vennix 1996). It is arguable whether or not the modeller changes to becoming a (single individual) reflector in the second stage (Zagonel 2004: 34, 46). Any researcher has to employ a certain scientific scepticism throughout the whole process, but probably the greatest task for her would be to facilitate group-wide reflexive control. Regardless how the roles of the modeller will finally be described, it has become clear that a 'separated' or 'objective' research is impossible in any social system dynamics consultation. The research process itself has to be participatory and client (learner) oriented (Scholl 2004). In *Figure 5* some of the core ontological categories of system dynamics are revisited and assigned re-structurated meaning, introducing some of the nomenclature of structuration theory to it, as detailed in this chapter.

The described process of system reproduction is just roughly sketched. Nevertheless, the development of an integrative grounding reflecting on the duality of structure, as noted at the very beginning of this paper, is not only providing much opportunity to the future of system dynamics. In turn, structuration theory, along with the main stream of social theory, can benefit from system dynamics, being an almost 'ideal' structural language, opening wide and varied social phenomena to scientific research. This would be the realisation of a task Forrester envisioned some good forty years ago for system dynamics: to become that "interdisciplinary language", providing especially for the social sciences.

6. Prospectus from a radical structurationist view

Theory constitutes practice. Therefore, good theory most likely constitutes good practice. With a radical version of system dynamics, re-emphasising its structural core, dualism in the social sciences can be deconstructed. System dynamics can then help to establish a new structurationist approach, supplying the required language for describing (and embracing!) social change. Such a formal or ideal language would aid structuration theory, but also the social sciences as a whole, in becoming scientifically more accessible. This can be achieved through raising the empirical significance of its findings in transcribing 'normal' narratives into structural narratives. The paradigmatic position of system dynamics is, in the best sense of the word, emancipatory and liberating. To speak in the words of a great German philosopher: system dynamics, as

re-structurated in this paper, bears the metaphorical power, as well as the structural thinking, needed to aid the individual in its emergence from (1) self-incurred immaturity, as well as (2) forceful oppression by 'the system' it reproduces.

The requirements for a system dynamics epistemology have already been outlined: the realness of the observer, as well as the realness of the perceived social systems has to be taken into account. A non-objectivist, context-aware explanation of cognition and model-building capacities of the individual is demanded. This points towards an evolutionary epistemology with reference to a moderate (or modest) constructivism, which leads towards a neurobiological epistemology or "neurophilosophy" (Irrgang 1993: 260 et seqq.) and possibly to a system dynamics theory of cognition.

The 'stitch' to be made to knit system dynamics and structuration theory together at an ontological level, is represented by learning through and about mental models in the process of structuration while executing reflexive control. Learning, in this regard, is the main mechanism of system reproduction through reflexive adaptation. The process of system reproduction, as shown, contains the possibility (power) to stabilise *and* change the system alike. Any social theory built around the duality of structure, has to develop a theory of learning, incorporating and explaining concepts of mental models, elicitation, qualitative mapping and routine building through generalisation of behavioural and structural patterns. With such a theory, not less than the necessary and sufficient conditions of system sustainability are described. [33]

The task given by Lane (2001) is not fulfilled. Yet, this paper might have been able to give (a) a slightly different deduction of the tasks ahead, by looking closely at system dynamics, its strengths as well as its grey corners, and (b) a glimpse into the opportunities for both system dynamics as well as structuration theory in re-focusing on structure and the ability of system dynamics to provide a structural language for the social sciences. The basic findings of this paper, on all accounts, are as follows:

- Mental models, their building and elicitation processes are central to a radical structurationist version of system dynamics.
- Structure and its reproduction through actors knowledge, portrayed in these mental models, is at the head, heart and tail of a radical structurationist version of system dynamics.
- Qualitative modelling and mapping is not the prelude to true system dynamics, but its most essential part.
- A system dynamics theory of learning can (and will!) yield insights into the means and ends of system reproduction.

The emphasis of a new integrative grounding of system dynamics within the duality of structure puts the tasks assigned by Lane (2001) in concrete terms:

- *better communication with the rest of the social sciences through clarification of system dynamicists' language*: refining the meanings assigned to system dynamics concepts in chapter five, and, as a by-product, clarifying system dynamics ontology an epistemology ("the rule books").

[33] It could well be the case that a restructurated system dynamics could not only overcome the paradigmatic division of objectivism/subjectivism, but also the regulatory/change antagonism. Probably a restructurated system dynamics would resemble a post-paradigmatic science – a New Science, as Peter Finke of Wiesbaden University likes to say.

- *engage into critical discussion with social theorists about the nature of the method*: engaging into empirical structuration research with the help of a re-structurated system dynamics, including a research design providing for close feedback evaluation, and publishing the results in journals and conferences outside the system dynamics community.
- *learning from, but avoiding at the same time, pure subjectivism*: developing a coherent method of qualitative system dynamics firmly routed within the structural foundations of the field, centred around a process view on skilful realisations.
- *development of an integrative grounding, reflecting on the "duality of structure"*: requires a system dynamics theory of cognition and learning, the likewise greatest endeavour yet to be undertaken.

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Figures

Figure 1

- Paradigmatic framework for the analysis of social theory -

Burrel and Morgan 1797

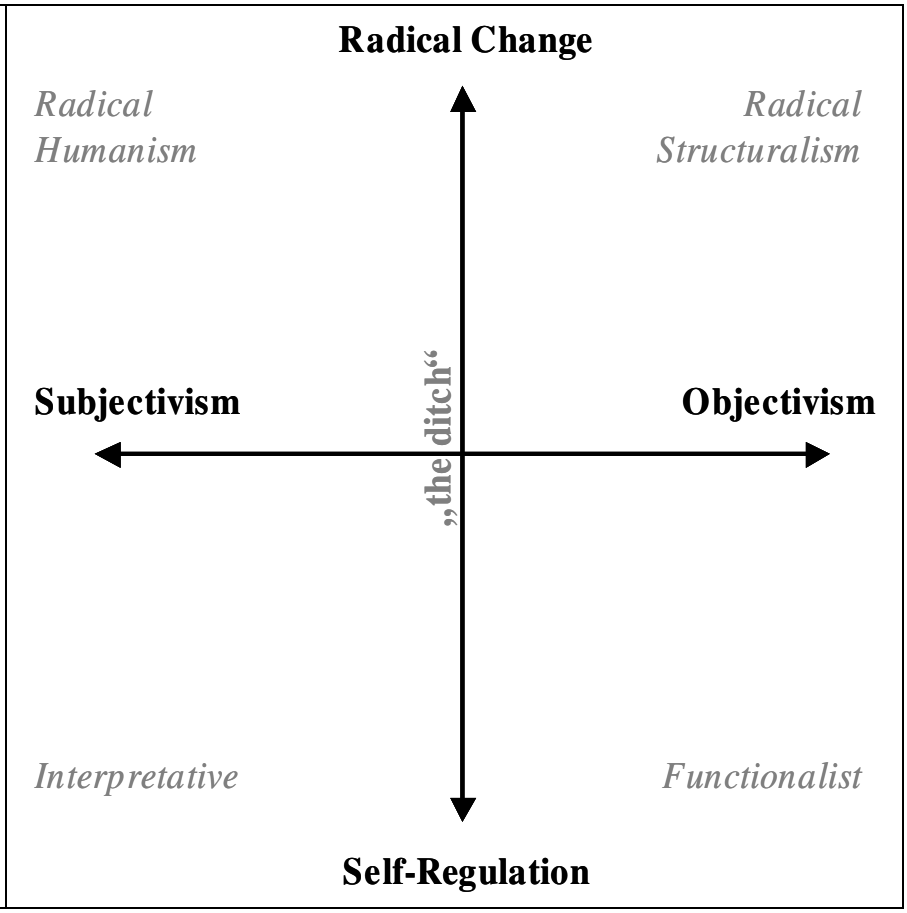

Figure 2

- Types of social theory -

Röd 1994

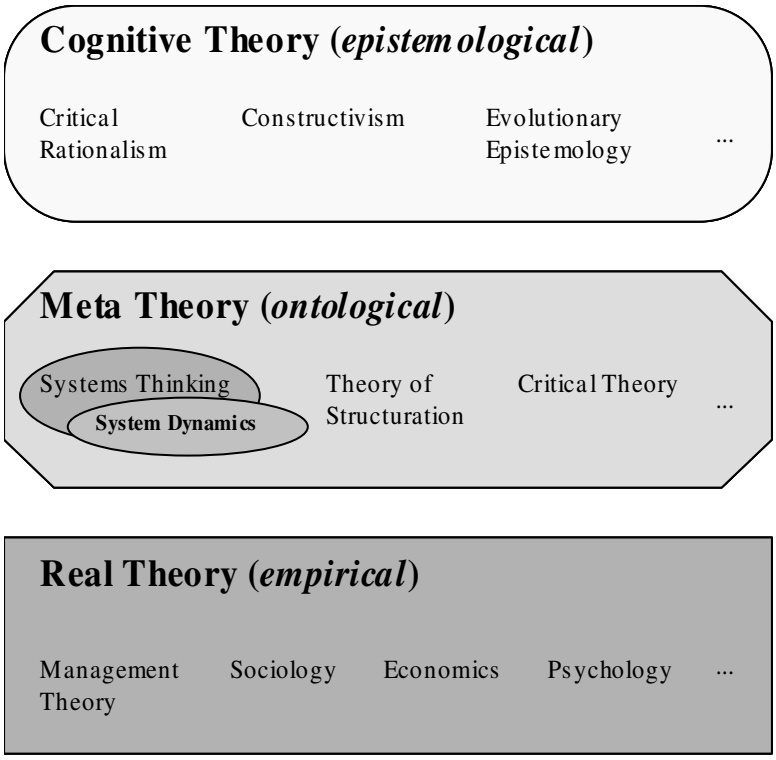

Figure 3

- Duality of structure -
Author's interpretation of Giddens 1984, 1997

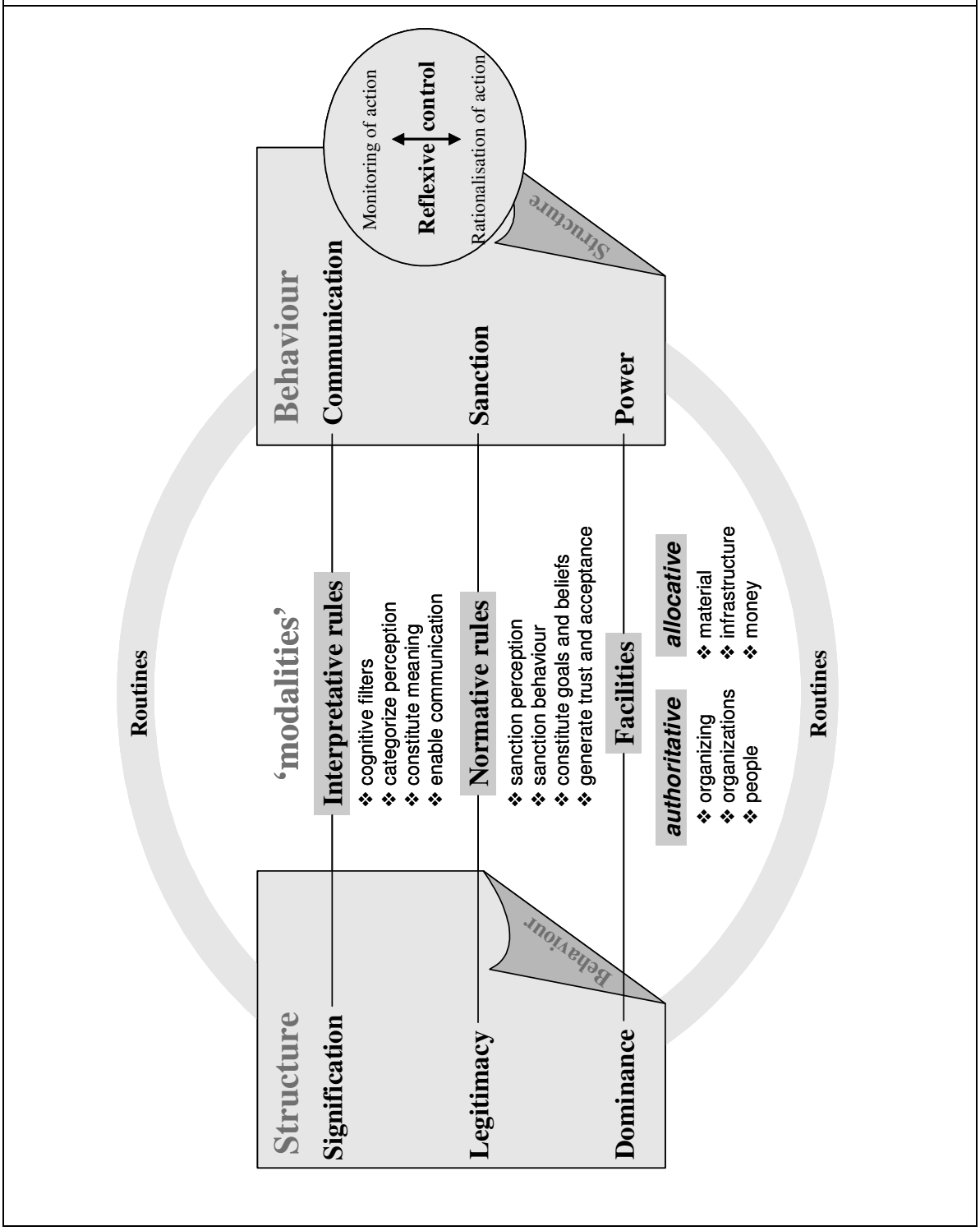

Figure 4

- Process (realisation) view on system dynamics -
Author's view

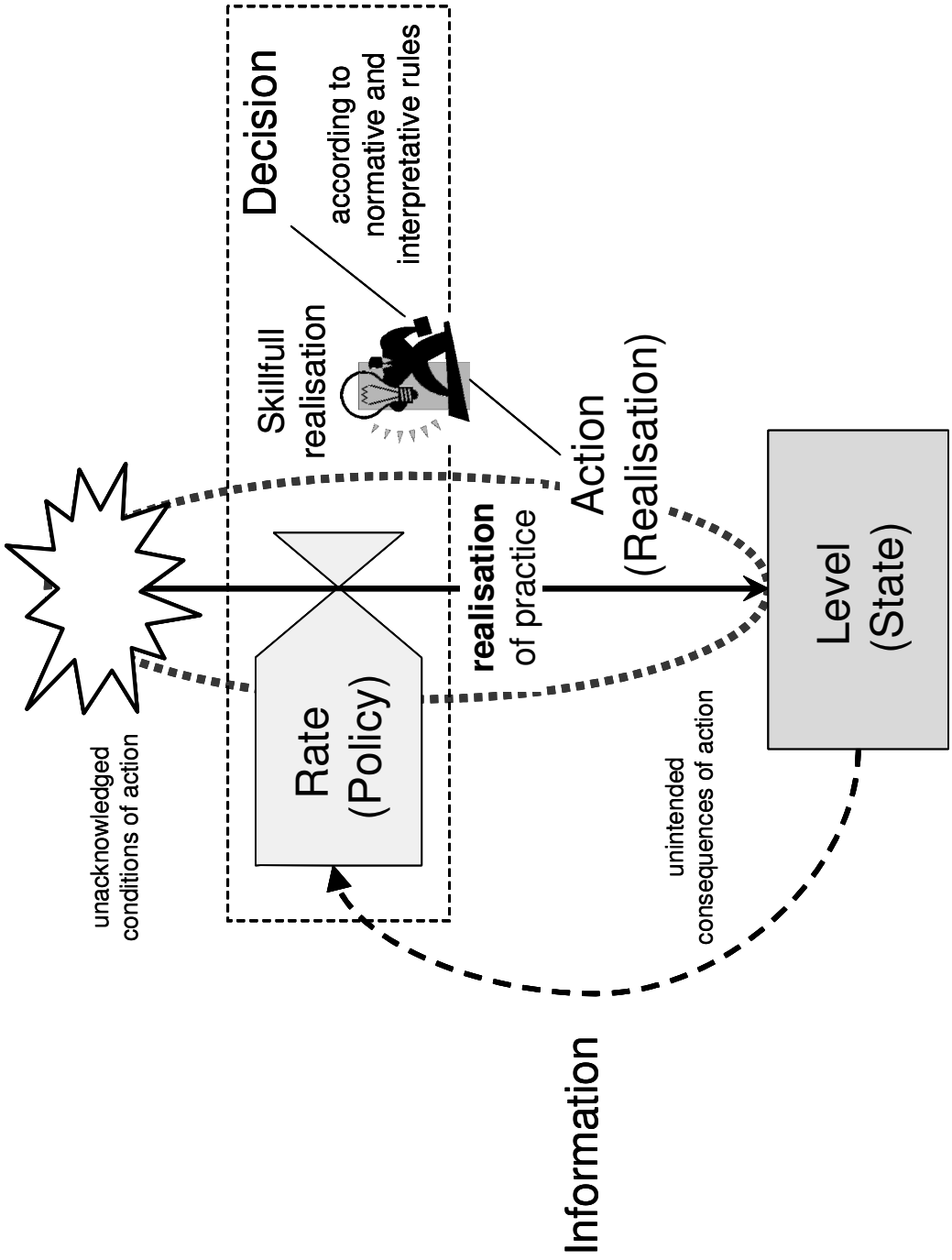

Figure 5

- Re-structuration of system dynamics -
Author's view on core ontological categories

Concepts / ontological categories	**Description**	**Re-structurated meaning**
Structure	• reproduced actors knowledge, laid down in mental models • decision rules, resources, relations between actors and resources • determines (enables and constrains) behaviour • can be described in structural narratives	Structure is a formal description of sustained (sedimented) actors knowledge about normative and interpretative rules, assigning authoritative and allocative resources

System	• complex whole, containing
	  • properties (rules, resources, relations) described and arranged in feedback loops, and stock and flow variables;
	  • as well as processes of routine interactions of actors, using structural properties and reflection on each others behaviour
	• Reproduction circuit
		System as a 'virtual' set-up of reproduced (reproducible) rules and resources, realised *ex post* in interactions of conscious actors.

Structuration	• monitoring of behaviour • 'theorising' about intentions and results of behaviour • learning about social processes, aided by elicitation and simulation methods • building of social routines, aided by the use of structural narratives • providing for system sustainability	Structuration refers to the conditions governing the continuity or sustainability of structures, and therefore the reproduction of social systems
Reflexive control	• control (management) of complex social systems • becoming aware of underlying mental models and sedimented social knowledge • facilitating learning processes • managing structuration	Reflexive control in and about social systems is managing structuration through the facilitation of learning processes

Learning	• central part of structuration processes
	• in and through (mental, verbal, formal, mathematical) models facilitating learning processes
	• understanding of structure
	• adaptation and transformation of common patterns of structure, aided by:
	  • generic structures
	  • canonised system models
	  • system archetypes
		Through the use of system dynamics in elicitation and qualitative mapping of mental models, reflexive control is aided in promoting structuration processes, thus ensuring system reproduction

Mental models	• images of knowledge • epistemic elements • actors organise their knowledge in and through them • contain structural (generic) knowledge about systems • reproduced actors knowledge • prerequisite for 'routinising' social action	Contextual knowledge and result of earlier structuration processes, sedimented within structure, thus, constituting its properties and, therefore, behaviour
Duality of structure	• de- and re-construction of dualism between objectivism and subjectivism • structure as a constraint and enabler of social action • structure as medium and result of social action • reciprocal constituency of structure and behaviour	The constitution of social reality on a cognitive level
System dynamics	• integrative theory of complex systems • to increase knowledge retention by providing an organizing framework • structural thinking, combined with (experimental) learning • trying to implement the idea of learning processes • learning as its central means and ends • structural, feedback-driven view of reality	Structural (ideal) language to aid learning within and about social systems

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