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Toolbox for Tomorrow

Exploring and Designing Sustainable Systems

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Exploring and Designing Sustainable Systems

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To Sphurti and Aarth,
and to you,
for tomorrow

"Each is given a bag of tools, a shapeless mass, a book of rules, and each must make, ere life is flown, a stumbling block, or a stepping stone." Anon

"If man can will his motives freely, then man is free in spite of the fact that all actions follow with necessity from motives." Nicholas Georgescu-Roegen[1]

[1]Georgescu-Roegen, N., *The Entropy Law and the Economic Process,* Harward University Press, Cambridge, 1971, p. 179.

Foreword

I was present at the birth of this toolbox.

Like any promising child, it has grown up to be something very different from, and more complex than, and more profound than I had expected.

We who attended the birth consisted of a few dozen teachers and preachers of sustainable development from many countries of the world. We expected that the toolbox would be a simple compilation of the many teaching devices we collectively had developed to try to get across insights about sustainable and unsustainable systems—why fishbanks are systematically overfished, why electric power systems are often either underbuilt or overbuilt, why nations either do not develop, or develop too far. Our teaching devices took the form of games, films, stories, jokes, interactive computer models, books, graphs, data bases—you name it. Earnest teachers use every tool they can lay their hands on.

Anupam Saraph knew most of these tools well, and had a creative flair for assembling information in useful ways. So he got the job of bringing together the toolbox. Little did we, or he, know what would grow out of that assignment.

First, being what we in the U.S. call a "computer jock," Anupam built a computer framework to organize things. He wrote a program that could help a user access and use and interpret any tool in the toolbox. The tools would be stored electronically. The toolbox had become a disk.

Then, being an educator in the best sense of the word, Anupam thought how marvelous it would be if the users of the toolbox could make their OWN tools. We all had learned an enormous amount in the process of turning overfishing or electricity planning into computer graphs and games. We had come to understand the systems we were modeling much better. And we had come to a deep, almost wordless, appreciation for the power of models—most especially the models in all our heads, which each of us experiences as "truth." Anupam wanted to share that "meta-" level of learning about systems and modeling and "truth". So he started building into the toolbox a facility for the user to do his or her own modeling. The toolbox had become an authoring program.

Sometime during the work on this phase of the project, Anupam went off the deep end, as some of us in the original planning group describe it, or became astonishingly creative, as others would say. He invented a new kind of modeling. The toolbox became not only a disk, not only an authoring program, but a new language (we call it "Anupam-speak") and a new philosophy.

That new language and philosophy and way of modeling is described in the following text. It is an attempt to solve the worst problem of previous computer modeling methods, including the method called system dynamics, upon which Anupam's toolbox is founded. We who use system dynamics are brilliant at modeling physical structures, populations, stocks and flows of pollutants -- THINGS that are countable, measurable, and follow the physical laws of the universe. We can follow the nonlinear, feedback-modulated, dynamic interactions of these THINGS, their formations and lifetimes and obsolescences, with ease and elegance. We can learn many useful insights about the world that way—insights that would revolutionize market economics, for a starter, if more people understood them.

But our models have been curiously lacking in PEOPLE. Certainly we model populations, aggregations of people of certain ages and attributes, people who consume certain things and die if they don't get enough of them. But the people we have modeled have not been explicit ACTORS. They haven't had MINDS, much less mindsets (or, in Anupam-speak, "reactivities"). They have certainly not been permitted, in the workings of our models to CHANGE their minds. They have never come together to form ORGANIZATIONS. We may have represented the obvious influences of real organizations in our models, but we have not permitted those organizations to EVOLVE, to LEARN, or to FAIL.

This book is Anupam Saraph's first attempt to describe a modeling method, language, and philosophy that is centered on actors, minds and mindsets.

Frankly, I find this text hard going, as hard going as learning any other new language. But then as one gets older, one finds it more difficult to learn languages, and as one is sunk deep in the tradition of one kind of modeling, one is not so plastic about learning another. I have watched the effect of Anupam's "visible" and "invisible" toolboxes on younger folks, and I have seen it to be almost explosive in its ability to generate new kinds of understanding, and new ideas about how to be an effective actor in real systems, as well as in computerized systems.

And I deeply appreciate the basic insight of this "toolbox,"—that "systems" arise, ultimately, out of consciousness; that the most profound way to understand a system is to understand its consciousness; and that the most inexpensive, elegant, and lasting way to change a malfunctioning system is to change its consciousness.

You never can tell, when you are present at a birth, what sort of wonders may have just been launched into the world.

Plainfield, USA, June 28, 1994 Donella H. Meadows

Preface

Mathematical models have been used increasingly in every theoretical and practical aspect of operation especially with the advent of the computer. The computer, with its wizardry in processing strings of inputs and collections of tables to produce outputs of all kinds of permutations chants an electronic oracle for modern times. It is not unusual to discover that the model, or theory, behind this extensive computation is often lost into the memory cells of the modeller. To the user, the product becomes a calculator. It is unnecessary to question or even know why the numbers add up the way they do. It is no longer possible to question why these calculators need the inputs they do or produce the outputs they do. In doing so the user is turned into an automata to feed numbers and receive numbers.

Models are usually couched in abstractions and with numerous parameters, most of which have no correspondence with an observable real world. It is no wonder therefore that users are happier with models that turn them into automatons than otherwise. In a special effort of the International Development Research Centre (IDRC) of Canada, to get models concerned with *development policy*[2], to policy makers in south and south-east Asia, my colleagues and I were confronted with the need to be or even devise an artificial "front-end" to existing models. It was clearly difficult to expect steps towards sustainability unless the tools at hand could be accessed.

As part of the management in business environments I was often confronted with the question of *sustaining* the organisations I was a part of. Having the good fortune of being equipped with the tools of problem solving, knowledge systems (especially MIS, databases and specialists in specific areas) and systems (especially System Dynamics and Beer's Viable System Model), it was possible for me to develop insights into the use of these tools for managing change and sustaining the organisations. Syslogic, a tool to explore the potentials of systems, and NOW, a computer language to represent models in Syslogic originated in my efforts to address these requirements.

The International Network of Resource Information Centres[3] (INRIC), of which I am a member, has among its members both developers and users of models. The experience of even such a community with close interactions has been that it is extremely difficult to *share* models. In the summer of 1991, Prof. Dr. Dennis Meadows hosted a workshop at the University of New Hampshire (USA) for the Futures Research Group at RIVM[4]. The object was to define a toolbox that can collect tools for

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[2]The Information Centre for Development Policy Modelling, Poona, India discharged this role.

[3]Also referred to as the Balaton Group as their annual meetings take place at lake Balaton in Hungary.

[4]The participants at the workshop included Dr. Gerald Barney, Institute for 21st Century Studies, USA, Prof. Dr. Hartmut Bossel, University of Kassel, Germany, Drs. Thomas Fiddaman, University of New Hampshire, USA, Drs. Jodi de Greef, RIVM, The Netherlands, Prof. Dr. Dennis Meadows, University of New Hampshire, USA, Prof. Dr. Donella Meadows, Dartmouth College, USA, Ir. Aromar Revi, TARU, India, Prof. Dr. Jan Rotmans, RIVM, The Netherlands, Drs. Anupam Saraph, Simlab, India, Drs. Anjali Sastry, Sloan School of Management, MIT, USA, Dr. Bert de Vries, RIVM, The Netherlands and Dr. Barbara van der Waals, University of New Hampshire, USA.

resource dynamics, if such a thing can be constructed at all. The illustrious scientists being present from across the world concluded that such a toolbox was indeed needed if sustainable development were to be made possible but the task of drawing specifications of such a toolbox was left to a possible future exercise.

In May 1992, Dr. Bert de Vries and Drs. Jodi de Greef of the Rijksinstituut voor Volksgezondheid en Milieuhygiëne (RIVM), at Bilthoven in the Netherlands, were requested by the Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer of the Netherlands (VROM), to construct the prototype of such a toolbox. I was asked by the RIVM and Interfacultaire Vakgroep Energie en Milieukunde (IVEM, the institution executing the contract), at the University of Groningen in the Netherlands, to undertake the complex task.

The project focused from the very beginning on a product, compatibility with existing tools and sharability of the tools. Inheriting the logical framework of Syslogic and NOW, the project advanced rapidly into a product. The conclusion of this exercise was the development of a *visible toolbox* in the form of software. The existence of the software importantly demonstrates the possibility of *sharing* models to understand, communicate and manage systems in a correspondence with reality.

This prototype *visible toolbox* was then tested at two workshops with participants from different research centres across the world and at two annual meetings of the Balaton Group. In parallel my research for tools that can indeed operate on systems to alter their ability to sustain themselves recognised that *systems themselves change*. Out of the concern to operate on a moving target, a theory of organisation of systems was born. It was also recognised that the domain of the study had far exceeded the one originally planned.

At this point, while the project of construction of the prototype toolbox had ended, it was recognised that the insights of Syslogic, the tool on which the visible toolbox was based, along with the more general , general theory of organisation of systems were valuable tools. There was therefore a value in the scientific documentation of the efforts. It is therefore that Prof. Dr. Ton Schoot Uiterkamp and Dr. Ir. Wouter Biesiot suggested that this document be written. There was, not surprisingly, more than enthusiastic response from several colleagues (especially Prof. Dr. Donella Meadows, Dr. Bert de Vries, Drs. Jodi de Greef, Prof. Dr. Malcolm Slesser, Prof. Dr. Peter Allen and Prof. Dr. Hartmut Bossel) from different research centres as this would provide a valuable possibility to share the insights generated in the project.

The following pages are what have resulted as a consequence. They are my efforts to communicate the nature of tools that are used to understand, communicate and manage sustainability and change, the tools that were designed by me to do so and finally the consequences and limitations of the tools designed thus. The work presented here is thus a partial summary of my contribution to an ongoing search by scientists in diverse scientific fields for tools to understand, communicate and manage change. This historical background is presented here to help put what follows in a proper perspective.

Groningen, The Netherlands, April 1994 — Anupam Saraph

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Acknowledgements

Every artefact is the consequence of the acts of several systems that organised in some meaningful relationships. This treatise is also the artefact of many such systems that organised around meaningful relationships. As the common participant, or actor if you will, I can attempt here to express my gratitude to all those actors who formed systems with me. Each system has been fun. Unique. And wonderful even in its reorganisation. Thank you for all those times that you were ready to move to new states. Thank you for all those times your inscripts did not get the better of you. Thank you for not being exceptions to the universe of change. Thank you for all those times you showed your reactivity to your reactivities, and thank you for *showing* me that all this is indeed a reality. And for your love.

It hardly makes sense to list the relationships; that would not capture the essence (unless you used the theory of organisation of systems!). But it does make a lot of sense to list out the participants; at least those that have consciously or unconsciously formed systems of long life times to shape this treatise.

My parents, Usha and Datta, without whom I would not be the system I am. Prof. Dr. Sohan Modak without whom my reactivities may never have been sharpened. Prof. Dr. Alok Bhattacharya, Dr. Sudha Bhattacharya, Prof. Dr. E. C. Subbarao and Prof. Ir. Keshav Noori without whom I may never have organised into these systems. Prof. Drs. Jaswant Krishnayya without whom I may never have gained reactivity to systems. Prof. Dr. Donella Meadows without whom I would never have sustained a reactivity to systems, sustainability and change. Dr. Bert de Vries without whom Syslogic may have been an unrealised dream. Drs. Jodi de Greef without whom the path for the theory of organisation of systems may have been impossible. Dr. Ir. Wouter Biesiot without whom this artefact may never have aquired this shape, Prof. Dr. Ton Schoot Uiterkamp without whom this work may never have reached you.

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The many at VROM, who felt it worth the while to have such a toolbox. The Jessie Smith Noyes Foundation and especially Steven Viederman for immense confidence in our efforts. The boards of RIVM and IVEM who put the responsibility of the toolbox on to me. The members of the Balaton group from over twenty countries who cared, and for whom everything mattered.

For this artefact, among other things, the major role has been of Prof. Dr. Ton Schoot Uiterkamp and Dr. Ir. Wouter Biesiot. Without them this treatise would surely not have taken this shape. Prof. Dr. Donella Meadows also played a major role over the last several years in crystallising much of what is written. I cannot say enough about their role in bringing this artefact to you. The important role of the reading committee in carefully reading, and appreciating the importance of this document for the change that is necessary can not be understated. The important role of Sunil Mehta in his association in publishing. They are also responsible into bringing this document to you.

My wife, Arundhati, who was the first reader to induce me through several rounds of rewriting. My daughter Sphurti for the inspiration and first step of simplifying. To my son Aarth for beginning the meaning to tomorrow by beginning his days when I was finished for the day!

And finally to all those who I do not mention or forget to mention and you, dear reader, are all who make this worth the while for a better tomorrow!

Prologue

From the earliest times, humans have needed to understand the environments (systems) they are a part of. They have used this understanding to communicate or manage the system. This treatise aims to equip you, the reader, with a simple set of 'tools[5]' to understand, communicate and manage[6] the systems around you that are in *constant change*. It is almost needless to remark that the aim of equipping you with such tools is not an altogether new aim. Ever since humans attempted to understand their systems, they attempted to share their tools of understanding.

It will not be inappropriate to point out that this exercise, however, is unusual both in its presentation and what is being presented. The few remarks in this prologue are therefore intended to equip you with the tools to add to your collection of existing tools the new tools designed to operate on the systems that undergo constant change.

It is not uncommon to encounter a management crisis. The Report to the Club of Rome[7] in 1972 declared an environmental management crisis for the *planet* earth. The statements were reiterated by the Brundtland Commission[8] in 1987 and accepted by international legislation at the UNCED conference in Rio de Janeiro in 1992. Management crisis, such as the global crisis, suggest the failure to apply tools to either manage, communicate[9] or understand the systems we live in. The immediate motivation, then, is to seek to collect together such tools that can make it possible to apply them to our systems. This is an exercise which has been addressed by several scientists before[10].

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[5]Tools is used here to include methods and instruments.

[6]The three ultimate purposes of all *operation* are understanding, communication or management.

[7]See Meadows, D. H., D. L. Meadows and J. Randers, *The Limits to Growth*, Earthscan Publications Ltd, London, 1972.

[8]See World Commission on Environment and Development, *Our Common Future*, Oxford University Press, Oxford, 1987.

[9]The effectiveness with which these messages raised general concern about the state of the world suggests that we have at least tools to communicate problems of systems if not the systems themselves.

[10]See for example the effort of Meadows to compile and evaluate different methods (Meadows, D. H., and J. M. Robinson, *The Electronic Oracle: Computer Models and Social Decisions*, John Wiley and Sons, Chichester, 1985) the exercise of Bossel in collecting together several simple systems tools (Bossel, H., *Umweltdynamik*, te-wi Verlag GmbH, Munchen, 1985; Bossel, H., *Ecological Systems Analysis: An Introduction to Modelling and Simulation*, German Foundation for International Development, Feldafing, 1986 and Bossel, H., *Modellbildung und Simulation: Konzepte, Verfahren und Modelle zum Verhalten dynamischer Systeme*, Vieweg, Wiesbaden, 1992), the exercise of Barney in collecting models for policy-makers (Barney, G., and S. Wiltson, *Managing a Nation: The Software Source Book*, Global Studies Centre, Arlington, V. A., 1987), the exercise of the International Development Research Centre (IDRC) through the Information Centre on Development Policy Modelling (ICDM) in India to serve as an repository on models and modelling methods, the effort of Slocombe and the World Conservation Union's (IUCN) commission

The tools collected in such studies are excellent at undertaking to address the specific questions they were designed to ask. In doing so, however, they restrict our understanding, communication or management to the confines of the *domain*[11] addressed by these tools[12]. This is surely not an issue for those who wish to restrict themselves to this domain. Usually the concern about restricting ourselves to address these domains arises when one crisis of our times is replaced by a newer one.

The growing concern for the environment and sustainability in the west and north, accompanied by the urgency for survival in the east and south raise the question of what the environment really is. It is clear that tools that define it as something out there, or as nature or as anything non-human cannot reconcile the dilemmas we face. As already pointed out earlier, the design of the toolbox was initiated to have tools that can address our needs to operate on the world with precisely these concerns.

In such an exercise, to construct a toolbox, it is first necessary to examine the nature of the tools that are commonly resorted to in order to address the question of change and sustainability. How can indeed such tools be compared? What are the benchmarks which allow us to evaluate a tool? Since it is these questions that can give us insights into designing new tools, this is precisely what is addressed in part one of this treatise. For reasons of the inadequacy of the existing tools, some of which are described in part one, new tools were designed to address the domain of *change* and *sustainability*.

The toolbox, which consists of two tools: Syslogic (or the logic of systems) and the general theory of organisation of systems are described in part two. Syslogic is a tool which specifically allows to identify systems in a fashion that their identification can be *shared*[13]. It also allows to explore the potentials of such systems once they are identified. It can thus be possible to trace if desired potentials lie within the realisable potential or even the potential of a system.

The general theory of organisation of systems is a tool which allows to explore the *life cycles* of organisation of a system. It provides a building block for all organisation, *irrespective* of the physical nature of the organising substance. Such building blocks can then be used for both analysis as well as design[14]. Like bricks or atoms, building blocks are tools that offer a variety of complex structures to be built. It is outside the scope of this treatise to encompass all of these. Part two describes these tools. Appendices three and six also summarize these tools.

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on environmental strategy and planning (CESP) efforts through the tools for sustainability working group and at a different level the work of Leonard on collecting tools or methods for systems (Leonard, A., "Making Alphabet Soup: Blending VSM, STS and TQM" in *Kybernetes* 21(4):33-42, 1992).

[11]Domain is bounded knowledge. Usually in a domain is bounded by the *interest* of someone or something.

[12]See particularly the caution of Meadows in this respect (Meadows, D. H., and J. M. Robinson, *The Electronic Oracle: Computer Models and Social Decisions*, John Wiley and Sons, Chichester, 1985).

[13]This can be likened to the sharing of the understanding of molecules by chemists. Just as all chemists know what is meant by water or carbon dioxide irrespective of where, it can become possible to describe a system by means of its components which are universally identifiable.

[14]This use can be compared with the use of understanding of the atomic nature of matter which provided the possibility to understand the building blocks complex molecules were made of and synthesise molecules from building blocks.

Part three illustrates the use of these building blocks to understand organisations of common encounter, many of which have objects of study by traditional disciplines. Although the similarities and differences with the conclusions of traditional disciplines by using the unified framework of these tools is not pointed out, these will not escape the observant readers from such disciplines. It is hoped, however, that the advantages of such a unified framework are not missed out either.

Part two also describes the implementation of Syslogic in the form of a software, the *visible toolbox*. It also describes the language NOW, designed to represent models in Syslogic. Appendix four lists a simple model *adapted* to the language NOW. Appendix five describes the interactions of the *visible toolbox* to use the model for understanding, communicating or managing the modelled system.

It is not the role of any tool to prescribe. Tools allow operation which may result in prescription. Perhaps the choice of the user in using (or not using) a particular tool implicitly reflects the prescriptions of the user as it expresses the users desire to operate on a particular domain. In this treatise, whose purpose is to *present* the tools, prescriptions are kept down to those implicit or immediately resulting in the choice of the domain. The way these tools affect our ability to operate on the world for the purpose of understanding, communication and management are described in part three. Consequences follow from a set of accepted premises. These consequences can therefore be considered (an incomplete set of) *theorems* of the tools presented in part two.

It must be explicitly understood that the *complete* set of consequences is not presented. The choice of the theorems has been restricted to those having a direct relevance for the way we operate on the real world (for understanding, communication and management). Some application areas of importance like environment (which was an important concern for designing the toolbox), hereditary and evolution and designing automata are also presented due to their significance to present day concerns, as well as the counter-intuitive consequences the tools offer on these subjects. Some management principles[15] that follow as a consequence of the application of these tools to the world are also presented in part three.

Theoretically the general theory of organisation of systems can encompass Syslogic. Both are presented here as Syslogic is implemented in the form of usable software whereas the work on making the general theory of organisation of systems more accessible (as for example in the form of software) will be undertaken in an independent project.

Tools leave the burden of the *use* on the user. They only facilitate operation on a domain that the user wishes to operate on. Like all toolboxes, therefore, this toolbox has tools which cannot be expected to contain products that have been applied on the domain the tools operate on. It contains only tools that allow you to operate on the domain. It also contains illustrations on how you may use these tools.

The research program has been based on the clear recognition that every tool operates on a distinct and new domain. Having identified that it was necessary to develop tools to manage change, and therefore sustainability, the research focused on designing such tools. It is therefore the express concern of this treatise to focus on these tools and not on tools that address other domains.

All science is considered to consist of general truths. Of all those truths only some are considered fundamental or primary and the others are secondary or derived[16]. While the specific nature of

[15]Principles as considered throughout the treatise are theorems on which actions are based.

[16]"An almost boundless diversity of theorems, which are known, and an infinite possibility of others, as yet unknown, rest together on the foundation of simple axioms; and yet these are all *general* truths....Let us

science can be defined differently by different people at different times, it is generally accepted that science has to establish connections between facts of experience, of such a kind that we can predict further occurrences from those already experienced[17]. To do this we seek the simplest[18] possible system of thought which will bind together observed facts[19]. Simpler systems build on primary propositions rather than secondary propositions. It is possible to consider such simpler propositions as *building blocks* from which the world that it binds together can be constructed.

In this treatise we will attempt to move away from general truths towards primary propositions in order to identify a building block for the phenomenon of all organisations irrespective of their *physical* characteristic. It is only such tools that provide the building blocks of organisation that will allow us to operate on *changing* systems and therefore explore means to sustain them.

It is the practice of science to economise the expression of its general truths using special words which are either coined anew or borrowed from related ideas. It becomes necessary to understand the meanings of a word in the *context* of a study. It is precisely for this reason that a *glossary* is provided at the beginning of this treatise. Many words will undoubtedly have associations in different contexts. To do justice to understanding this treatise, it is necessary to substitute only the meaning indicated in the *glossary* for every occurrence of the words in the *glossary* unless otherwise stated. The *glossary* is therefore not a collection of definitions from dictionaries, but rather a *shorthand* reference for *this* treatise.

As I said above, the aim of this treatise is to equip you with a set of *tools*. I try to make this book a tool to reach to you in as much a conversation as I can. For it is when you gain *reactivity* to what is within, the purpose of this work is achieved. An exercise of communication is incomplete if there is only a one way traffic. Through this book, we engage in a relationship. I therefore take the liberty to *eavesdrop* onto my audience. I share this eavesdropping for reasons which can become clearer in the epilogue. The participation of my audience in this exercise gives the exercise an organisation and identity. It is undoubtedly the identity which is very important for any exercise.

I use footnotes extensively in order to preserve the logical flow of the argument. Footnotes are used to point out important parallel arguments, interesting related information, alternate interpretations, references and special meanings of words (on the use of the word for the first time). It is possible to skip my footnote excursions except when they are used to define meanings of words. In order to distinguish footnotes which describe the meanings of words, a special symbol (✋) is used.

A comprehensive index to the document helps access the ideas and cross reference them. The footnotes, however, are not indexed. All the tools and arguments mentioned within this treatise,

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define as fundamental those laws and principles from which all other general truths of science may be deduced, and into which they may all be again resolved. Shall we then err in regarding that the true science of logic which, laying down certain elementary laws, confirmed by the very testimony of the mind, permits us thence to deduce, by uniform process, the entire chain of its secondary consequences, and furnishes, for its practical applications, methods of perfect generality?" (Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, p.5).

[17]Einstein, A., *Essays in Science*, Philosophical Library, New York, 1934, p. 112.

[18]One which contains the fewest possible mutually independent postulates or axioms (*ibid*., p. 113).

[19]*ibid.*, p. 113.

unless explicitly stated otherwise, have been developed by me. For those who have thought similarly that I am unaware of, my sincere congratulations. If you grant me the words to argue, I accept all responsibility of error of reasoning. I seek therefore your endurance in following through my arguments which often needed to resort to shorthand especially for several of the concepts that I assemble in this excursion.

Conventions

Language	Words are used carefully throughout this document. Every word is only a shorthand for the meaning that its *context* gives it. The shorthand in the context of this treatise is made explicit in the glossary. Unless otherwise stated object names (nouns) refer to *classes* and not to individual or specific objects. For example tool refers to the class of tools and not a specific individual tool. Care is taken to avoid statements that can not be observed "universally". Throughout an emphasis is placed on the logical flow and the possibility to derive the tools and the argument.
✋	Highlights the footnote to indicate it refers to the meaning of word.
☝	Indicates that the preceding word has a special definition and is defined in the glossary
'tool'	The single quotes are used to refer to quotes within the treatise itself.
"The ability to..."	Double quotes are used to indicate quotes of colloquial usage or by someone indicated before the quote.
Change	Italics are used to emphasise a concept.
l level=level	This type face is used for examples.

Glossary

It was pointed out earlier that every domain uses words as shorthand for the general truths. It is therefore necessary to understand the shorthand of every domain in order to interpret its statements appropriately. The terms defined here are starting points to what is *meant on their use in this treatise*. This glossary therefore serves one important purpose: it provides a quick reference to the *shorthand* for concepts used in this treatise. It thus points out what these words mean in the context of this work. They should be taken to do no more.

In creating shorthand there are two possibilities: use familiar words in new contexts with *new concepts* for which they now become shorthand or to invent new terms[20]. While the first makes it easier to use the new concept by virtue of familiarity it makes it difficult to understand the new concept due to the familiarity of its use in another context. The latter possibility inverts the advantages. The first shifts the burden of correct interpretation and substitution on to the reader. The latter assumes the reader is unable to consciously *substitute* what is meant every time a word is used. In *this* exercise it is assumed that the reader *can and will* substitute every occurrence of the word in the *glossary* with the meaning stated here. Therefore terms familiar to the reader in some other contexts may be found to have different meanings in this treatise.

Throughout the treatise care is taken to avoid words that have anthropocentric connotations as shorthand. If concepts have a more anthropocentric parallel, or are *known* to deviate in clearly defined terms from any existing ideas, such is indicated in the footnotes. Some familiar concepts are sometimes expressed with different words or word equivalence's to owing to the intuitive simplicity to physical and biological sciences. Whenever such an exception is made, it is explicitly pointed out for those readers familiar with such a term in its "native" contexts.

Some of the concepts implied by the words undergo refinement and change during the course of the treatise. This becomes possible in the new *contexts* of the arguments in the treatise. For convenience new terms are not invented for the refined concepts in these new contexts. The reader should be aware of the constant effort to refine these concepts and consciously *substitute the concept for every occurrence of these words in appropriate contexts*.

Access Time: Access time is the time to retrieve a proposition☝ of interest. Typically access time comprises of a seek time (or the time to seek the partition that has the proposition of interest), search time (to search the proposition of interest) and read time (or the time to read or infer the proposition of interest).

Actor: An actor is anything that acts. Thus the thermostat which acts in response to the room temperature is as much an actor as a human. Throughout this treatise the word actor should be stripped of any "living" organism or human connotations.

[20]Every discipline has abundant examples of this choice. For example molecules are said to be "attracted" to each other, gravity is said to exert a "force", oscillations are said to "damp" etc. On the other hand word like quark, quasars, introns, exons, bucky balls etc. are free of meaning in most known contexts.

Adequacy: A tool☝ is said to be adequate if its structural☝ domain☝ contains only primary propositions☝ and can map the desired functional☝ domain.

Adequate Script: An actor has *adequate script*☝ if the actor☝ can respond to all events☝ that affect the actors desired event profile.

Analysis: A process of substituting (or identifying) *specific* elements in a general (set of) proposition(s)☝ is referred to as analysis in this treatise. This process usually requires the "observation" of a general proposition. An analytic statement can be both false and incorrect as it does not *follow* as a consequence of any simpler statements. This is used synonymously with the term *à posteriori* in this treatise[21].

Axiom: The word axiom is derived from the Greek verb αξιόω which means to think worthy. It is used to signify self evident truth☝ of so simple a character that it must be assumed true. It thus occurs as a premise of many arguments but as the conclusion of none. As this truth cannot be proved by any simpler proposition☝ it is taken as the basis of reasoning☝[22]**.**

Coding: Coding is a process where propositions☝ are expressed in a specialised 'language' of a target system☝ for storage, reading, writing, retrieval and inferencing.

Concept: A concept is a theorem. The theorem can change with axioms (experience) to allow better conclusions to be drawn from premises (observations). Thus the concept of table as something with four legs holding a flat surface *may evolve* to something holding a flat surface. The concept of triangle is synthesised from concepts of points and lines.

Correct: A proposition☝ is correct for an *observer* if it matches the observers observation.

Domain: A domain is bounded knowledge☝. Usually knowledge in a domain is bounded by the *interest* of someone or something[23].

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[21]It is important to note that the terms synthetic and analytic have caused much debate and controversy in their exact meaning and equivalence to *à priori* or *à posteriori* (Kneale, W., and M. Kneale, *Development of Logic*, Oxford, London, 1962). For example Kant (*ibid.*, p. 356-358), Bolzano (*ibid.*, p.265-266), Frege (*ibid*., p. 445-449) and Quine (who refused to accept such a distinction; *ibid*., p. 644-646) use these terms differently and with different equivalence's. The equivalence of synthetic to *à priori* and analytic to *à posteriori* as used here is following Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p. 210 owing to the intuitive simplicity of his use for those familiar with the use of the words synthesis and analysis (*ibid.* p. 205) in physical and biological sciences. In contrast a dictionary of philosophy (e.g. Flew, A. *A Dictionary of Philosophy*, Macmillan, London, 1979, p. 11) gives three contextual meanings for the terms analytic and synthetic. "A statement is an analytic truth if and only if the concept of the predicate is included in the subject; otherwise if it is true it is a synthetic truth" (cf. 1). "A statement is an analytic truth or falsehood if it can be proved or disproved from definitions by means of only logical laws, and it is synthetic if its truth or falsity can be established by other means" (cf. 2). "A statement is an analytic truth if it is true by virtue of the meanings of the words it contains; a statement is true if it is true in virtue of the way the world is" (cf. 3).

[22]Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p. 125.

[23]Collins Cobuild, *English Language Dictionary*, Harper Collins Publishers, London, 1992, p. 418.

Event Class: An event class is a set of events☝ that are transformations of the same stock☝. Thus food surplus and food shortfall belong to the same class of events as they concern themselves with food stock.

Event: An event is a happening that falls out of the "normal" pattern of the observer. An event is thus something relative to the observer. Events evoke a response of some kind. Thus while sun rising is an "event" to somebody watching the darkness of the night, it is not an "event" to somebody who is in a windowless room when the sun rises. An event is necessarily a "process" that lasts over a duration. It can be recognised☝ only when it lasts at least as long as the duration that the observer samples for its occurrence[24].

Feedback: An actor☝ has feedback if the actor responds to events☝ generated by the actors acts.

Flow: A flow describes movement. Stocks *flow* from one stockpile to another. Everything flows[25].

Functional Domain: The propositions from any domain☝ that can be viewed as secondary propositions☝ or the conclusions that follow from some simpler propositions in the domain are referred to as the functional domain[26].

Indifferent Actors: In contrast to concerned actors☝ who influence a relationship through their response to events☝ generated by the state of the relationship (concern), indifferent actors are actors who influence a relationship with indifference. Thus indifferent actors do not respond to events generated by the state of the relationship in the system☝.

Information: Information is available knowledge☝. Information is thus relative to an actor☝ and depends on the actors ability to recognise☝ the knowledge. The use of this word is to be avoided unless referring to the availability of knowledge.

Inscript[27]: An inscript is a set of instructs☝ responding to an *class of events*☝. Inscripts are formulated as rules☝. An actor☝ lacks an inscript to an event☝ if the actor has no instructs☝ to respond to the event. An actor lacks an inscript to an event *class* if the actor has no rules to respond to that class of events. An inscript is usually a stochastic rule but could be a probabilistic rule, as for example in coding, so as to generate "random" responses.

Instruct[28]: An instruct is the actors☝ act of responding to an event☝.

Isoform: Systems☝ comprising of the same actors are isoformic. If the actors have a variant inscript☝ then the two systems are *response isoforms*. If the actors enjoy different relationships, then the systems are *reactive isoforms*.

Knowledge: As used here, knowledge is simply a set of propositions☝ about the world.

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[24]For example humans sample visual, auditory and tactile impressions 18 times a second (Withrow, G., *The Natural Philosophy of Time,* Oxford University Press, London, New York, 1980, p. 73-74).

[25]Heraclitus as quoted in Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 144.

[26]The set of propositions in the functional domain can also be considered as a "consequence set".

[27]An inscript is the same as a rule in a system of human actors.

[28]An instruct would be the same as decision in a system of human actors.

Law: A law is a postulate☝ that specifies a means of combining or reducing propositions☝ in the argument. Often laws have an empirical basis.

Logic: Logic is derived from the Greek word λόγοs which usually means word or the outward manifestation of any inward thought. The same word was also used to denote the inward reasoning☝ of which words are an expression.[29]

Manager: Every actor☝ by the acts of modifying something is a manager. Management science and business communities generally consider only the special case where the manager is someone who oversees other actors.[30]

Organisation: Organisation is the process of establishing or severing a relationship between existents.[31]

Overhead: Overhead is the use of the something in order to make possible its own use. For example the memory used in the computer to keep track of the files on the computer is an overhead. This memory then is unavailable to do the tasks that you want the computer to do. In this context it is the use of accumulators themselves to allow their use.

Postulate: A postulate is a proposition☝ which is necessarily demanded as a basis for argument. Often postulates define the practical conditions required to make the argument valid.

Potential of a system: The potential of a system☝ is the set of event☝ profiles that can be potentially generated by the system.

Problem: Problems are event☝(s) not desired by someone or something. The undesired event(s) are sometimes referred to as symptoms.

Propositions: Propositions are statements about the real world that describe facts or relationships. Compound statements are referred to as secondary propositions or theorems ☝. Simple statements that cannot be further reduced are referred to as primary propositions.

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[29] "...the true science of logic which, laying down certain elementary laws, confirmed by the very testimony of the mind, permits us thence to deduce, by uniform process, the entire chain of its secondary consequences, and furnishes, for its practical applications, methods of perfect generality" (Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, p. 5). Sometimes Logic, "in its practical aspect", is interpreted as "a system of processes carried on by the aid of symbols having a definite interpretation, and subject to laws founded upon that interpretation alone" that aim to facilitate: "the means for eliminating those elements which we desire not to appear in the conclusion", "to express final relation among the elements of the conclusion by any admissible *kind* of proposition, or in any selected *order* of terms" and "expressing relations among certain elements, whether things or propositions". (*ibid.*, p. 6-10.). This implies that several systems could be designed with their own laws founded on unique interpretations.

[30] The word manage derives from the masculine Italian "maneggiare" meaning handling things. It also stems from the more feminine French word "ménager" meaning using something carefully (Johnson, P., and J. Gill, *Management Control and Organisation Behaviour*, Paul Chapman Publishing Ltd., London, 1993, p. vii).

[31] It must be pointed out that organisational theories in management sciences have used this word to mean institutions of people. Institutions of people can also establish and severe relationships. It is only this process irrespective of the physical nature of the existents establishing relationship that are implied in the use of the term organisation.

Reactivity: Reactivity is the actors☝ ability to recognise☝ and respond to an event☝. Actors can recognise the same events but respond differently. Actors can also react identically to different events. When actors recognise the same event and respond identically then they can be said to have the same reactivity.[32]

Realisable potential of a system: The realisable potential of a system☝ is the set of event☝ profiles that are realisable in practice, given the dictate of the external actors☝.

Realised Potential of a system: The realised potential of a system☝ is the event☝ profile realised through particular instructs☝ on part of the internal actors☝.

Reason: Reason is derived from the Latin word *ratio* from *reor* meaning to think. Reasoning has been defined as the progress of the mind from one or more given propositions to a proposition different from those given[33].

Recognise: The word recognise is often assumed to involve a self aware act of cognition. It is important to note that there is no self awareness implied in the meaning used here. The word is used throughout the treatise to mean only a mapping or matching or fitting in the sense a lock 'recognises' a right key. Recognition is possible only if the recogniser and the recognised are in proximity (sometimes this can be facilitated by tools which simulate proximity; e.g. the information network in the form of telephones, computer networks, televisions etc.). Recognition is possible only when proximity lasts at least as long as the duration that the recogniser samples for what it can recognise[34]**.**

Relevance: A tool☝ has relevance if all secondary propositions☝ in its structural domain☝ (if any) are relevant in the tool. A secondary proposition is relevant in a tool, if it can be derived from a set of primary propositions which can be demonstrated to be shared with the structural domain of the tool. It follows that if all the propositions in the structural domain are primary propositions, the tool has relevance.

Role: Role of an actor☝ refers to the ability of that actor to recognise or participate in a system ☝.

Stocks: Stocks are accumulations of things. Anything that can accumulate can be a stock. From books, arms, people to frustration, love and anger there are millions of stocks in the world. In a relationship, acts of actors transfer some stocks from one pile to another. It is important to recognise that stocks buffer systems☝: It takes long to fill or deplete stocks. The larger the stock, the greater its ability to buffer the system; to be resilient to changes in inflows or outflows from the stock. Events☝ are stocks filled within a certain range. Sustaining☝ a relationship is sustaining the stocks that are central to the relationship. If stocks *rise or fall* out of proportion, the relationship may not be sustained.

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[32]Non-response on recognition is also a response at a meta level as it alters the reactivity of the actor.

[33]Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p.15. Reason has ambiguous meaning in its use and has been used (esp. by Kant; see for e.g. Kant, I., *Critique of Pure Reason*, Translated by W., Schwarz, Scienta Verlag Aalen, 1982) to include all our cognitive powers.

[34]The sampling rate of the human sense organs is approximately 16-18 per second for visual, auditory and tactile impressions (Withrow, G., *The Natural Philosophy of Time,* Oxford University Press, London, New York, 1980, p. 73-74).

Structural Domain: The propositions from any domain☝ that can be viewed as the simpler propositions☝ or the premises from which the balance propositions of the domain can be concluded are referred to as a structural domain[35].

Surprise behaviour: A event☝ profile is surprising if it does not follow the trend.

Sustain: The word sustainable comes from the Latin verb *sus-tenere* meaning to uphold. This in turn is derived from the Greek verb *tenein* (τενειν) meaning to stretch. This Greek verb also means to carry the weight of something by support from below. While the colloquial treatment or operational meaning of the concept☝ of sustainability varies widely, the basic meaning of sustainable as *upholding something in time* remains universal[36].

Synthesis: A process of synthesising new proposition(s)☝ from simpler propositions is referred to as synthesis in this treatise. The *truth*☝ of a synthetic proposition can be established by reason alone. The *correctness*☝ of the synthetic statement depends on the truth of the simpler propositions that make up the synthetic statement. This is used synonymously with the term *à priori* in this treatise[37].

System: A system is variously defined using different tools☝ *for* systems. The general concept ☝ of a system is that of a functional unit of reality.

Systems Analysis: Systems analysis is a process of *identifying* simpler *specific* elements of observed systems☝.

Systems Synthesis: Systems synthesis is the process of *constructing* a system☝ from simple building blocks.

Theorem: A theorem is a secondary proposition☝ which can be proven from the axioms☝, laws ☝, definitions and postulates☝ that make up the theory.

Tool: While the typical dictionary meaning of tools refers to an implement used to operate on an object, some dictionaries[38] also refer to a tool as any object skill, idea. Throughout this treatise the word tool is used to refer to anything that is used to operate on something with the purpose of either understanding, communicating or managing what it operates upon. Thus concepts☝ are as much tools as microscopes. Some tools take up physical form while others exist only as concepts. Thus a theory to understand the nature of elements is as much an tool as is the microscope or hammer.

Toolbox: A collection of tools☝ to address a specific domain☝ is referred to as a toolbox.

True: A proposition☝ is true if it is accepted as true by convention or if follows as a *consequence* of the process of reasoning. Truth of a statement is thus independent of an observation[39].

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[35]The propositions in the structural domain can also be considered as the "axiom set".

[36]Vries, H. J. .M., de, *Sustainable Resource Use: An enquiry into modelling and planning*, Rijksuniversiteit Groningen, Groningen, 1989, p. 17.

[37]See footnote 21 on p. xxiv.

[38]Collins Cobuild, *English Language Dictionary*, Harper Collins Publishers, London, 1992, p. 1543.

[39]Logic refers to a proposition as being true if and only if it is regarded as true (Flew, A. *A Dictionary of Philosophy*, Macmillan, London, 1979, p. 330). This notion of truth establishes truth as *ad-hoc* convention. The use of the concept truth of propositions as following as a consequence of reasoning emphasises the

arbitrary nature of the propositions but enables the *reproducible* derivation of the truth of a proposition. This also allows to distinguish between the truth and correctness of a proposition. For example it is possible to say “all swans are white” as being true as *convention* and show it is incorrect for an observer who can see black swans.

Part One

Foundations for the Toolbox

This part presents the concepts that create a context for the tools in the toolbox.

Chapter 1

Tools for Designing a Toolbox

Tools

While the typical dictionary meaning of tools refers to an implement used to operate on an object, some dictionaries[40] also refer to a tool as any object skill, idea. Throughout this treatise the word tool is used to refer to anything that is used to operate on something with the purpose of either understanding, communicating or managing what it operates upon. Thus concepts[41] are tools, too. Some tools take up physical form while others exist only as concepts. Thus a theory to understand the nature of elements is as much a tool as is the microscope or hammer.

The primary role of any tool lies in its *recognition*[42] of a domain[43]. The tool *may* additionally modify the domain it can recognise. It is thus possible to identify the domain of any tool by identifying what it recognises (and modifies). Using this definition, design of (new) tools follows from identification of the domain that one needs to recognise or modify. Conversely it is possible to explore the role of a tool in facilitating the exploration and modification of a domain. Tools thus also facilitate the exploration and modification of the domains they can recognise.

Perhaps one of the most illustrative examples of the importance of a tool in facilitating exploration and modification of new domains is that of the microscope. Somewhere between the years 1590 and 1609 a Dutch optician, Zacharias Janssen, placed a combination of a concave and a convex lens at

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[40] Collins Cobuild, *English Language Dictionary*, Harper Collins Publishers, London, 1992, p. 1543.

[41] A concept is a theorem. The theorem can change with axioms (experience) to allow better conclusions to be drawn from premises (observations). Thus the concept of table as something with four legs holding a flat surface *may evolve* to something holding a flat surface. The concept of triangle is synthesised from concepts of points and lines.

[42] The word recognise is often assumed to involve a self aware act of cognition. It is important to note that there is no self awareness implied in the meaning used here. The word is used throughout the treatise to mean only a mapping or matching or fitting in the sense a lock 'recognises' a right key. Recognition is possible only if the recogniser and the recognised are in proximity (sometimes this can be facilitated by tools which simulate proximity; e.g. the information network in the form of telephones, computer networks, televisions etc.). Recognition is possible only when proximity lasts at least as long as the duration that the recogniser samples for what it can recognise.

[43] A domain is bounded knowledge. For a more detailed explanation of the domains to include the concepts of structural and functional domains please see p. 6.

Zacharias Jansen (1590)

Robert Hooke (1635-1703)

Antonie van Leeuwenhoek (1632-1703)

Kaspar Friedrich Wolff (1759)

Theodore Schwann (1810-1882)

Johannus Lipershey (1590?)

Galileo Galilei (1610)

Microscopy and related fields **Telescopy and related fields**

Figure 1 *A Partial history of optical tools and the domains they opened up.*

the end of a tube and produced a crude microscope[44]. The tool opened up a "startling dimension" to biological sciences[45]. New "philosophers" took the tool and applied it to biological study. Robert Hooke (1635-1703) was able to discover the cellular structure of living things with the aid of the newly found tool. With the aid of the microscope, the Dutch scientist Antonie van Leeuwenhoek (1632-1703) made pioneering studies in bacteriology. He ventured into embryology, observing spermatozoa and spent time studying protozoa, hydra reproduction and the flea life cycle[46]. It was possible for Kaspar Friedrich Wolff to point out that there were no pre-formed organs in the egg. He also pointed out that the early life history of the individual was also a record of the annals of its race in his *Theoria Generations* (Theory of Generations) presented as his doctoral thesis in 1759[47]. There is little doubt that Theodore Schwann (1810-1882) would not have been able to establish the cellular basis of all tissues, in his *Mikroskopische Unterschungen* (Microscopic Researches published in 1839), were microscopy not possible[48].

Telescopy offers another such example. The tool of compounded lenses was used by another Dutchman, Johannes Lippershey, to design a tool for seeing at a distance[49]. The tool was used by Galileo Galilei in 1610 to make numerous astronomical observations. He observed that Jupiter was accompanied in its orbit by four small Moons. This was important because it showed that an orbiting planet could carry its own satellites with it, and effectively countered the argument that if the earth moved as Copernicus proposed, the Moon would be left behind. He also observed the phases of Venus which were contrary to those expected if the universe were geocentric and could be explained by the Copernican solarcentric theory[50]. The study of astronomy and our 'world view' about the

[44]Trattner, E., *Architects of Ideas: The story of the worlds great thinkers*, The New Home Library, New York, 1942, p. 189.

[45]Ronan, C., *The Cambridge Illustrated History of the Worlds Science*, Cambridge University Press, Cambridge, 1983, p. 392-393, 431-436.

[46]*ibid.*, p. 394.

[47]Trattner, E., *Architects of Ideas: The story of the worlds great thinkers*, The New Home Library, New York, 1942, p. 194-195.

[48]*ibid.*, p. 200-202.

[49]*ibid.*, p. 189.

[50]Ronan, C., *The Cambridge Illustrated History of the Worlds Science*, Cambridge University Press, Cambridge, 1983, p. 341-343.

relative position of our planet in the universe changed completely after the tool of telescopy became available.

Had a tool in the form of the Greek geometers tool of ellipses not been available, it would have been impossible for Johannus Kepler (1571-1630) to have revolutionised the concept of uniform circular motion of planets about the earth[51]. It was the use of the tools of classes of curves that allowed Kepler to put forth the heliocentric theory with elliptic paths of planets.

It is difficult to imagine how John Dalton (1766-1854) could have proceeded to develop his atomic theory of elements had a like of Robert Boyle's (1627-1691) tool in the form of theory of elements (which contrary to the belief that matter comprised of earth, air, water and fire postulated that air was not elemental but a mixture of elements) been non-existent[52]. It follows that William Prout (1786-1850) could scarcely have established that all atoms are compounds of hydrogen atoms without an atomic theory[53]. The study of the composition of the world changed from alchemy to chemistry with these simple and yet penetrating tools.

It has been pointed out that the tool of agriculture was one of the earliest (human) tools that changed the face of the earth[54]. With the tool of agriculture it was possible to produce enough for the requirements of a growing community than what could be harvested during a hunt.

While the above illustrations indicate an important role tools *must* play in shaping or changing the direction of societies[55], not all tools necessarily play such a revolutionary role. The important observation from the examples is that tools necessarily provide an ability to match or fit or recognise a new domain. For example the microscope provided the ability to match or fit or recognise the world of microscopic particles. Some tools can additionally provide the possibility to modify the domain they provide the ability to fit or match or recognise. For example the atomic theory provided the ability to match or fit or recognise atoms and the ability to manage them.

Since tools recognise and sometimes modify a *specific* domain[56], there can be no truly competing (classes of) tools, only competing domains[57]. It can therefore be concluded that the choice of a tool itself implies more about the *individual preference for the domain* of action than about the tool! For example, the screw and the nail cannot be considered competing tools. The nail operates on the domain of permanent binding, the screw on the domain of reversible binding. The preference of the user to permanent or reversible binding decides which tool is used and has little to do with the ability of the nail or the screw to hold together the two objects they bind. Only when the user does not

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[51]*ibid.*, p. 338-339 and Weyl, H., *Philosophy of Mathematics and Natural Science*, Princeton University Press, Princeton, 1949, p. 156.

[52]*ibid.*, p. 436-438.

[53]Lakatos, I., *The methodology of scientific research programmes: Philosophical Papers*, Worrall, J., and G. Currie, Eds., Cambridge University Press, Cambridge, 1978, p. 43, 52-55.

[54]See Ponting, C., *A Green History of the World*, Penguin Books, London, 1991

[55]It is therefore not surprising that primates have often been referred to as the "toolmakers" by scientists studying evolution.

[56]See p. 3.

[57]This is so because if tools were *true* competitors, they need to operate on precisely the same domains. By our definition of tools this would mean that only the same tool competes with itself.

understand the precise domain differences or does not care about the precise domain differences does his action seem to indicate 'competition' between tools. As *users* of tools, the preference to one or the other tool is purely a matter of the *domain* we wish to operate upon and is not a reflection on the ability of one or the other tool to do better (or worse) what it is designed to do[58].

Since the domains of tools are usually not made explicit, it is possible to interpret a few familiar propositions in the domain of the tool as its domain. This leads to everything becoming a domain for the tool. For example a hammer can be said to nail things together. It is therefore no wonder that with a hammer at hand everything tends to become a nail. It is true[59] and correct[60] that the hammer can operate on a nail very well. To drive in a screw, however, a screwdriver is usually more appropriate than a hammer. This misuse of tools is not uncommon when the rigour to understand the domain is not exercised. It needs to be understood that every tool gets its value from being able to operate on a (possibly unknown but) precise domain. To confuse it to be applicable across all domains can, and usually does, lead to disastrous consequences.

It is no surprise therefore to observe historically that the further away the domain of the tool from the domain recognised by the prevailing tools, the longer will it take for it to be the preferred tool. The more surprising the operation (uncommon understanding, unusual viewpoint or strange modification) of the tool, the longer it may take for the tool to make impact.

Domains of Tools

Since it is the domain which characterises a tool, it is important to understand in greater detail what exactly a domain is. Each tool can be described by a set of properties or by a set of propositions. Properties are "observational" propositions. Such observation is based on other propositions and no factual proposition (property) can ever rest on experiment alone[61]. The distinction between theories and empirical basis is thus non existent[62]. It can then be clear that the "factual" propositions as "observed" (or can be deduced) by a tool are only as a consequence of the propositions that make up the tool. All propositions that can be observed (deduced) from the tool can collectively be said to constitute the *functional*[63] domain of the tool. All propositions that constitute the basis (or building blocks) for the "observations" made by the tool can be said to constitute the *structural*[64] domain of

[58]The relativity of observations of the frames of the two tools could in fact be sharp and thus make it easier for us to identify which agrees with the domain we wish to operate on. If we adopt a *static* viewpoint, which refuses to accept the relativity of what is better has to do with a frame of reference that one wishes to operate on, then we will judge one tool as better (or worse) than another (when we should mean that the tool is better or worse to operate on the domain of our interest).

[59]A proposition is true if it is accepted as true by convention or if follows as a *consequence* of the process of reasoning. Truth of a statement is thus independent of an observation

[60]A proposition is correct for an *observer* if it matches the observers observation.

[61]Lakatos, I., *The methodology of scientific research programmes: Philosophical Papers*, Worrall, J., and G. Currie, Eds., Cambridge University Press, Cambridge, 1978, p 16.

[62]*ibid.*, p. 16.

[63]The term functional here means consequential. The term *conclusions* can be treated synonymous with the term functional domain in this treatise.

[64]The term *premises* can be used as a synonym with the idea of a structural domain in this treatise.

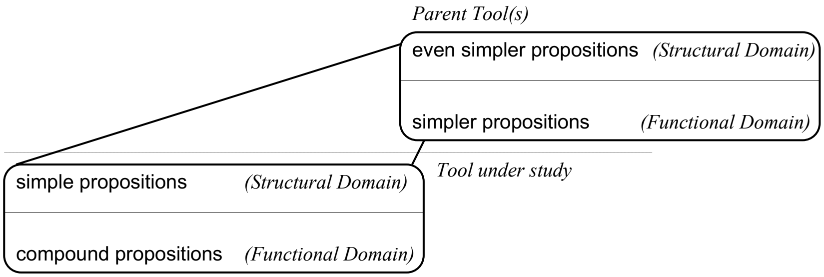

Figure 2 *The structural domain of all tools contains propositions derived using other tools (unless the proposition in the structural domain is primary like an existential statement). This is usually a design decision of the designer of the tool. The compound propositions in the functional domain are generated through a process of mapping. Mapping is usually carried out by the user of the tool through application of the structural propositions to the world. Sometimes the designer of a tool provides some compound propositions as they are intended as the users preferred area of operation.*

the tool. From an understanding of logic or reason it should be clear that the propositions that make up the structural domain are simpler than those which constitute the functional domain[65] (See Figure 2).

A tool therefore makes possible and *at the same time* constrains the factual propositions that it can allow us to "observe". In making possible such "observation" the tool is an extension of the "senses" of the user of the tool[66]. The scope of the tool can thus be made evident by documenting the propositions that make up the structural domain of the tool. The propositions in the structural domain of the tool can be "observational" propositions, derived from the use of other tools, or propositions free from the use of other tools (sometimes regarded as "primary").

The choice of the propositions in the structural domain rests on the designer of the tool. It is natural to include those propositions in the structural domain as will be necessary to derive propositions of interest in the functional domain. It is obvious then that not all tools can compare with each other in how they present the "real world"[67]. The fictional nature of every tool cannot be more emphasised.

[65]Popper made the observation that the content of a statement (proposition) *a* and the content of another statement *b* is lower than the content of the statement *ab*. He pointed out that, however, this increased content came with the price of increased improbability. Thus if *Ct* was used to specify content of a statement and *p* to specify the probability of the statement, $Ct(a)<=Ct(ab)>=Ct(b)$ and $p(a)>=p(ab)<=p(b)$. Popper thus observes that growth of knowledge requires theories of increasing content which is not possible without coming up with improbable propositions (See Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 217-220). However a system to *imply ab* under certain conditions makes it possible to make statements of higher probability and yet provide the possibility for several implications with high content.

[66]Lakatos, I., *The methodology of scientific research programmes: Philosophical Papers*, Worrall, J., and G. Currie, Eds., Cambridge University Press, Cambridge, 1978, p. 23.

[67]Einstein has pointed to this by indicating that the "fictitious character of fundamental principles is perfectly evident from the fact that we can point to two essentially different principles, both of which correspond with experience to a large extent" (Einstein, A., *Essays in Science*, Philosophical Library, New York, 1934, p.

Every tool represents a convention created by its designer. Since the conclusions drawn by every tool rest on propositions in the structural domain, and the truth of each proposition in the structural domain in turn rests on the tools to observe them (unless they are primary), it is evident that every conclusion is a convention following from the convention of the premises.

Let us consider a tool, *T*, that addresses a specific domain. The domain, *D*, of this tool is chosen by the designer from a whole range of propositions, *RP*. Let us assume that the user wishes to operate on a domain *D'*[68]. If there is complete overlap in *D* and *D'* then we have an ideal tool[69]. Structural equivalence of tools implies a functional equivalence. The converse, i.e. structural equivalence following from functional equivalence, is not necessarily true[70]. While the complete set of propositions in the structural domain of a tool can be stated it is usually impossible to state the complete set of propositions in the functional domain.

The mapping from the structural to the functional domains is usually carried out by the user of the tool. It is thus subject to both the bounds of the structural domain and the mis-interpretations of the user. Many tools provide the framework to allow the user to substitute the "variables" in a proposition mapped in to the generalised functional domain[71]. They thus provide a general map with the possibility to draw specific conclusions (or make specific observations).

Axiomatization is the process of the logical binding together of the premises as simpler propositions (structural domain) and observations or conclusions as secondary propositions [72] (functional domain). Axiomatization of a tool provides an excellent statement that exposes the structural and functional domains of the tool. Once the simpler propositions are stated, it is then possible that *new* or yet unobserved secondary propositions can be concluded through the process of mapping. Axiomatization thus provides the formal tool to predict observable phenomena *à priori*.

Euclidean geometry is perhaps the best known tool that is axiomatised. It provides for a whole spectrum of observations of flat surfaces[73] that are not possible without resorting to axiomatization.

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17). Quine has also not spared words to point out that "the totality of our so called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even pure mathematics and logic, is a man made fabric which impinges on experience only along the edges." (Quine as quoted in Kneale, W., and M. Kneale, *Development of Logic*, Oxford, London, 1962, p. 645).

68 See Kuipers, T., R. Vos, and H. Sie, "Design Research Programs and the Logic of their Development" in *Erkenntnis* 37:37-63, 1992, p. 41-42 for an application of a similar method to describe properties of products.

69 More formally one can express the symmetric difference between the domain of the tool and the desired domain as $(D{\sim}D')\cup(D'{\sim}D)$. In an ideal tool this will be an empty set (*ibid.*, p. 41).

70 *ibid.*, p. 47.

71 For example the microscope will always amplify an object to the same resolution, a voltmeter will always conclude what the potential difference across two points is irrespective of the specific instances of measurement.

72 Some simpler propositions are often referred to as *axioms* while others are referred to as *rules* or *laws.* The secondary (compound) propositions are usually called theorems.

73 It may be worth noting that in 1854 in a paper entitled "On the Hypothesis Which Underlie Geometry" Riemann launched a deep investigation into the surest facts about space. He realised that Euclid's axiom that space is essentially flat to be untrue and thus gave rise to the axiom of space of a constant curvature. This in turn was replaced in favour of local variations by Einstein's observations of the effect of gravitation on the

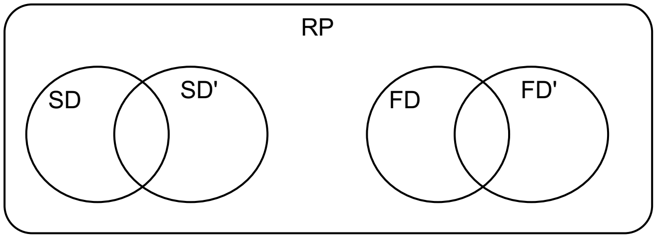

Figure 3 *The structural domain and the functional domain are subsets of the range of propositions of the real world. This figure illustrates the relationships between the desired and actual structural and functional domains and the range of propositions. SD is the actual structural domain of a tool, SD' is the structural domain that the user wishes the tool had. FD is the actual functional domain of the tool and FD' is the functional domain that the user wishes to operate on. RP is the range of propositions about the real world.*

With Euclidean axiomatization it becomes possible, for example, to *predict* that two chords of a circle which are equal must be equidistant.

It is possible to approach a design problem through modifying a structural domain in order to accommodate required structural characteristics[74] (which are usually identified by criticism of an existing tool) or conversely search for an appropriate structural domain that satisfies a desired functional domain. The former is the easiest recourse as the existing structural domain provides a starting point[75]. The latter is more difficult and perhaps the only guiding heuristic for this undertaking is that "we are seeking the simplest possible system of thought that will bind together the observed facts"[76]. The simplest possible system can only mean the simplest possible structural domain that can construct the functional domain.

The Method for Operating on Propositions

Method, by our definition, is a tool itself. The method for tool design is therefore a *meta*-tool (tool to design tools). Tools make operation possible by virtue of their ability to operate on a functional domain. Thus tools for tools operate by virtue of their ability to operate on tools. Since the structural domain of tools is a set of propositions, tools that can operate on propositions form the tools for tools. Thus the methods of axiomatization and mapping from the structural to the functional domain are also tools.

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curvature of light rays. This story tells us much about the utility of an axiomatic system as a means of consistently holding primary and secondary propositions together. (See for example Le Corbeiller, P., "The curvature of space" in Scientific American, *Mathematics in the Modern World*, W. H. Freeman and company, San Fransisco, 1968, p. 128-133).

[74]See Kuipers, T., R. Vos, and H. Sie, "Design Research Programs and the Logic of their Development" in *Erkenntnis* 37:37-63, 1992, p. 53.

[75]Lakatos cautions against the use of this approach as it tends to make the tool *irrefutable* (Lakatos, I., *The methodology of scientific research programmes: Philosophical Papers*, Worrall, J., and G. Currie, Eds., Cambridge University Press, Cambridge, 1978, p. 18-19).

[76]Einstein, A., *Essays in Science*, Philosophical Library, New York, 1934, p. 113.

The tools of reason[77] or logic[78] are precisely the tools that operate on propositions. The principles of logic have been argued to be "the laws of thought"[79], thus supposing that logic is the outward expression of an internal mechanism to infer conclusions from observations. Classically reasoning is either synthetic[80] (*à priori*) or analytic[81] (*à posteriori*)[82].

A classical *à priori* reasoning is an argument based on previously 'known' truths. This is also referred to as the synthetic or deductive method. In this method of reasoning we begin with the simplest possible ideas and combine them together. The oldest example of use of this method of reasoning is probably in Geometry. Beginning with simple notions of points, straight lines, angles, right angles, circles concepts of triangle (putting three lines together), right angle triangle (a triangle with an right angle), square (joining four equal lines at right angles) etc. are *synthesised*. In deductive

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[77] Reason is derived from the Latin word *ratio* from *reor* meaning to think. Reasoning has been defined as the progress of the mind from one or more given propositions to a proposition different from those given.

[78] Logic is derived from the Greek word λόγos which usually means word or the outward manifestation of any inward thought. The same word was also used to denote the inward reasoning of which words are an expression.

[79] Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, especially p. 39-51. It needs to be pointed out that recent years has seen much debate about the exact nature and role of reason and logic. Haack (Haack, S., *Philosophy of Logics*, Cambridge University Press, Cambridge, 1978, p. 238-242) views this debate as "psychologism" when logic is taken to be descriptive of reasoning or the way we think (as by Kant and Boole), "weak psychologism" when logic is viewed as prescriptive for our reasoning (as by Pierce) and "anti-psychologism" when logic has nothing to do with the mental process but only with propositions that are "public" (as by Frege). However while one process may be "private" and the other "accessible", it can hardly be denied that both logic and reason are concerned with methods of drawing reproducible inferences from available premises or propositions.

[80] A process of synthesising new proposition(s) from simpler propositions is referred to as synthesis in this treatise. The *truth* of a synthetic proposition can be established by reason alone. The *correctness* of the synthetic statement depends on the truth of the simpler propositions that make up the synthetic statement. This is used synonymously with the term *à priori* in this treatise.

[81] A process of substituting (or identifying) *specific* elements in a general (set of) proposition(s) is referred to as analysis in this treatise. This process usually requires the "observation" of a general proposition. An analytic statement can be both false and incorrect as it does not *follow* as a consequence of any simpler statements. This is used synonymously with the term *à posteriori* in this treatise.

[82] It is important to note that the terms synthetic and analytic have caused much debate and controversy in their exact meaning and equivalence. For the different uses of these terms by Kant (p. 356-358), Bolzano (p.265-266), Frege (p. 445-449) and Quine (who refused to accept such a distinction; p. 644-646) the reader is referred to Kneale, W., and M. Kneale, *Development of Logic*, Oxford, London, 1962. The equivalence of synthetic to *à priori* and analytic to *à posteriori* as used here is following Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p. 210 owing to the intuitive simplicity of his use for those familiar with the use of the words synthesis and analysis (*ibid.* p. 205) in physical and biological sciences.

arguments the premises (previously known truths) *imply* the conclusion. In such an argument, if the conclusion is false then one of the premises is false too[83].

It should be noted, however, that *à priori* truths are truths which are obtained without recourse to observation. Thus the conclusions of *à priori* reasoning are also referred to as *à priori* truths. The "laws of thought"[84], for example, are believed to be *à priori* truths. We have through it an *à priori* knowledge that "matter can not both have weight and be without weight". In contrast there is no 'law' to compel us to say that matter has weight. This is believed to be learnt by the *à posteriori* method.

In contrast *à posteriori* reasoning proceeds to infer from the consequences[85] of a general truth what the general truth is. This is also referred to as the analytic or inductive method. Properties of alloys as explained *à posteriori* from its composition, recession as explained *à posteriori* from data on the economy are examples of this reasoning process. The laws of combining proportions in chemistry, are also good examples of using this process to reason general truths from empirical observations. The statement that all squares are rectangles is also an analytic statement.

It is also possible that *à posteriori* truths can serve as *à priori* inputs to an argument. This distinction is often circular when considering secondary propositions. In such cases a synthetic statement is true at the mercy of the analytic truth and an analytic statement is true at the mercy of the synthetic truth[86]. For example the earth is round can be an analytic (*à posteriori*) statement which rests on the synthetic (*à priori*) concept round. On the other hand the synthetic concept round is based on the analytic concept of points. Kant's famous *Critique of Pure Reason* is perhaps most remarkable in describing the special case of *à priori* reasoning that is based on knowledge which has no *à posteriori* truths drawn from experience (for example the concept of God or immortality). Deductive reasoning with foresight to the consequences and diligence in comparing them with undoubted facts is sometimes visualised as a good method of investigating concepts.

Deductive systems can be presented in a special way: an *axiom*[87] system. Such a presentation includes the vocabulary containing the definitions and notational conventions used for the

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[83]Carney, J., and R. Scheer, *Fundamentals of Logic*, The Macmillan Company, New York, 1964, p.187-188.

[84]The laws of thought are: The Law of Identity (*Whatever is, is*), The Law of Contradiction (*Nothing can both be and not be*) and The Law of Excluded Middle (*Everything must either be or not be*). See for example Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, p. 39-51 where he 'derives' the laws of thought or see Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p. 117-125.

[85]Such consequences of a general truth are sometimes referred to as empirical knowledge, derived from the Greek word εμπειρια meaning experience or trial (*ibid.*, p. 256-257).

[86]See for example the argument of Kneale justifying the refusal of Quine to make distinction between *à priori* and *à posteriori* (Kneale, W., and M. Kneale, *Development of Logic*, Oxford, London, 1962, p. 646) where they point out that "statements of unrestricted universality seem to hover in our knowledge between empirical and *à priori*".

[87]See Haack, S., *Philosophy of Logics*, Cambridge University Press, Cambridge, 1978, p.19-22, Wilder, R., *Introduction To The Foundations of Mathematics*, John Wiley and Sons, New York, 1952, p. 3-22 and Carney, J., and R. Scheer, *Fundamentals of Logic*, The Macmillan Company, New York, 1964, p.293-313.

presentation, the axioms[88] or the self evident (*à priori*) truths, the rules of inference (or the laws of the axiom system, which are mostly postulates) and theorems[89] or secondary propositions. The advantage of such presentations is not only the ability to examine the completeness and consistency of such a system but importantly to serve as a *inference* system of knowing what will happen under what circumstances. It also presents itself to future extensions or modifications far more easily than other presentations.

Tools for Evaluation of Tools

It was pointed out earlier that no two (classes of) tools can *truly* compete. This does not imply, however, that the performance of a tool cannot or need not be evaluated. We are thus in need for a tool (or criteria) that can allow us to criticise the tools. Setting up criteria to "falsify[90]" a tool can not be a good criteria to evaluate the tool as it implicitly sets comparison with some "absolute" tool which can be the final arbiter of observation. Following the realisation that propositions follow from propositions alone, every tool is only mapping propositions. Alternate criteria in the form of "excess empirical content"[91] have been put forth to evaluate tools. Such criteria ignore that the characteristics of the tool and its utility are a property of its own and do not need comparison with some existing standard. The use of one tool or the other is purely an expression of the adequacy of the tool to operate on a *desired* functional domain. It does not express any absolute failure or inadequacy of an existing tool. We therefore need criteria to evaluate a tools performance on its own.

The structural domains of tools are *derived* from other tools (unless its propositions are primary). The structural domain of all tools is used for *mapping* a specific functional domain[92] (See Figure 2, p. 7). The tools for criticism can therefore rest on the these domains and the characteristics of their derivation (relevance, adequacy) and mapping (validity, consistency and completeness) alone. Criticism on the domains addresses the question of the mismatch (if any) between the actual structural or functional domain, *SD* or *FD*, of the tool and the desired structural or functional domain, *SD*' or *FD*'. The criticism of mismatch can be described as a statement of *inadequacy* of the tool for the task at hand.

Since mapping is the application of the method of operating on propositions, criticism on mapping examines the application of this method to the tool under study. Mapping (deductive reasoning) is *consistent* if both the conclusions (propositions in the functional domain) being false and premises

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88 The word axiom is derived from the Greek verb αξιόω which means to think worthy. It is used to signify self evident truth of so simple a character that it must be assumed true. It thus occurs as a premise of many arguments but as the conclusion of none. As this truth cannot be proved by any simpler proposition it is taken as the basis of reasoning.

89 Ambrose views theorems as *tautologies* (Ambrose, A., and M. Lazerowitz, *Logic: the theory of formal inference*, Holt, Rinehart and Winston, New York, 1961, p. 26).

90 Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 36-37.

91 Lakatos, I., *The methodology of scientific research programmes: Philosophical Papers*, Worrall, J., and G. Currie, Eds., Cambridge University Press, Cambridge, 1978, p. 33-34.

92 See Kuipers, T., R. Vos, and H. Sie, "Design Research Programs and the Logic of their Development" in *Erkenntnis* 37:37-63, 1992.

(propositions in the structural domain) being true results in contradiction[93]. Thus it is impossible in this system to assert both the conclusion as being true and false at the same time. Thus if we assert (structural domain) that whatever is, is and nothing can both be and not be[94] it is impossible to draw the conclusion (functional domain) that time exists and time does not exist at the same time. Deductive reasoning is *invalid* if the conclusions (functional domain) do not follow from the premises (structural domain). Thus in the example above, the conclusion that time changes is invalid from the premises. Another characteristic of mapping (deductive arguments) is *completeness*[95,96]. If the structural domain allows us to derive a proposition in the functional domain or its negation, then it is complete. Thus in the example above, if we cannot prove either that time is or time is not in the above argument; it is incomplete.

It is natural to ask when a tool is adequate, and by virtue of recursion, when a toolbox is enough. Criticism on the adequacy (or "enoughness") of a tool (and therefore a toolbox) can rest on examination of the *structural* domain of the tool. Propositions in the structural domain are the *à priori* inputs to the argument. These are often based on *à posteriori* truths ("observational" propositions or empirical knowledge).

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[93]"A deductive theory is consistent if no sentence can be both proved and disproved in it." Tarski as quoted in Hutten, E. H., *The Language of Modern Physics*, George Allen & Unwin Ltd, London, 1956, p. 33. Thus a system or a tool is consistent if it contains no contradictions. This also follows from the law of thought that nothing can both be and not be (See footnote 84 on p. 11).

[94]From the Laws of thought (See footnote 84 on p. 11).

[95]"A deductive theory is complete if every sentence formulated in the terms of this theory can be proved or disproved in it." Tarski quoted in *ibid.*, p. 33. This implies that the system is complete if of any two contradictory sentences at least one can be proved, . This follows from the laws of thought that everything must either exist or not exist (See footnote 84 on p. 11). It is interesting to note that it is required by Kneale as quoted in Haack (Haack, S., *Philosophy of Logics*, Cambridge University Press, Cambridge, 1978, p. 6) that "logic itself has to be a complete system".

[96]It is interesting to note Gödel's famous "theorem" stating the impossibility of arithmetic to map itself completely without giving rise to inconsistent propositions about arithmetic. Hilbert distinguished mathematical statements, (as 3+2=5) as being possible to construct out of elementary arithmetical signs, from meta-mathematics, as a system which explains which arithmetical formula can be derived from which others. It can be observed that the arithmetic is not able to operate on itself, but rather requires meta-mathematics to operate on it. This is precisely why Gödel needed to map arithmetic to meta-mathematical statements and then retranslate them to arithmetic in order to demonstrate the incompleteness of arithmetic. If one were to apply the definition of tool to arithmetic and reinterpret Gödel's observation in light of this definition, Gödel's observation can be restated to say that any system incapable of complete self 'recognition' will be unable to decide everything about itself. If all systems did in fact have self recognition, then cold bodies could turn into hot bodies spontaneously. The corollary is that any system capable of complete self recognition will be able to completely describe, understand or manage itself. One can perhaps view certain classes of Mandelbrot's fractals as capable of complete operation on themselves, thus being able to describe themselves at every level of recursion. Hutten points out that elementary Geometry is also shown to satisfy this characteristic (See Hutten, E. H., *The Language of Modern Physics*, George Allen & Unwin Ltd, London, 1956, p. 34-36).

It follows that if the scope of the *à posteriori* argument is questioned, the tool based on such reasoning is considered inadequate for addressing the new scope[97]. This can also be considered as a shift in the structural domain (*SD*) to a new preferred structural domain (*SD*').

A classic example of the modification of the structural domain in response to a domain shift is that of microscopy. The idea of a microscope was carried forward as phase contrast microscopy by the Dutch Nobel Laureate from the University of Groningen, Fritz Zernike. Later through modification of the structural domain the technique the modern electron microscopes have come to being. Telescopy follows a similar path: from optical to radio telescopy resolution has been increasing through the modification of the structural domain of the concept. Prout's theory of atoms as compounded Hydrogen atoms can be seen as modification of the structural domain of Dalton's atomic theory to more simpler propositions providing better resolution of all atoms known and unknown at that time.

Any *à posteriori* reasoning is likely to come to be questioned, eventually, as by its very nature it provides a secondary proposition of high content as an input for an *à priori* argument[98]. If tools do have such inputs into their structural domain, they are indeed likely be criticised eventually for their mapping characteristics as they get applied to conditions inconsistent with those required for the *à posteriori* inputs. Even if *à posteriori* reasoning by itself does not come to be questioned, the propositions provided by such reasoning as inputs to a tool are secondary. Thus it is likely that the tool be criticised for having secondary propositions in its structural domain.

If the propositions in the structural domain are not exclusively primary propositions they restrict the scope of the functional domain. This is so simply because a set of primary propositions can derive the secondary proposition now in the structural domain and the many other secondary propositions it has not been possible to derive so far[99]. Such a revision of a tool, that is replacing any compound

[97]For example Lakatos (Lakatos, I., *Proofs and Refutations: The Logic of Mathematical Discovery*, Worrall, J., and E. Zahar, Eds., Cambridge University Press, Cambridge, 1976, p. 6-9) illustrates a "conjecture" in the form of a dialogue between a teacher and students stating V-E+F=2 for all polyhedra (where V is the number of vertices, E the number of edges and F the number of faces). He then criticises the conjecture through an *counterexample* (p. 10). The counterexample is not a "polyhedra" as implicitly assumed in the conjecture. Thus this criticism identifies a discrepancy in the *à priori* inputs in the structural domain as addressed by the conjecture (tool) and the criticism (desired structural domain).

[98]For example Popper (Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 218) points out that the more the content of a proposition the less probable it is. It can also be noted that observations are collected from a *system.* The system however reorganises itself (as we shall see later in the treatise). Thus even if the observation is reproducible for a certain time, it need not be universally and always reproducible.

[99]For example Lakatos (Lakatos, I., *Proofs and Refutations: The Logic of Mathematical Discovery*, Worrall, J., and E. Zahar, Eds., Cambridge University Press, Cambridge, 1976, p. 70-72) illustrates the process of simplifying secondary propositions into simpler propositions. In order to derive the mathematical relationships between the edges, vertices and faces of polyhedra, rather than base reasoning on polyhedra as the starting point, he attempts to simplify a polyhedra. In order to do so, he describes polygons as a system of polygons consisting of a single polygon (monopolygons). He then states that polyhedra are a system of polygons which have more than one polygon (polypolygons). He also concludes that by definition for a single vertex V=1. He thus "proves" by definition of an edge that V-E=1. He further "proves" that for a polygonal system V-E=0. By fitting two polygons, he shows that there will be an excess edge (E-V=1).

or secondary propositions in the structural domain, moves the present structural domain into the new tools functional domain. Thus for example if a tool has propositions on feedback in its structural domain, and the proposition on feedback can itself be broken into simpler propositions, then a replacement of the proposition on feedback by simpler propositions will move feedback into the functional domain of the tool.

A tool has *relevance* if all secondary propositions in its structural domain (if any) are relevant in the tool. A secondary proposition is relevant in a tool, if it can be derived from a set of primary propositions which can be demonstrated to be shared with the structural domain of the tool. It follows that if all the propositions in the structural domain are primary propositions, the tool has relevance.

Secondary propositions are derived from other tools (perhaps an *à posteriori* argument). Such propositions do not necessarily contain information about the source domain from which they were derived. As there is no easy way to examine the source domain of the tool in order to explore the simpler (or primary) propositions relevance can *not* be easily established. This loss of relevance can make a tool inadequate by virtue of irrelevance.

For example the observation of exponential decrease of chess pieces on the chess board as the game proceeds is valid; but it is important to notice that it renders tools based on such an observation inadequate to operate on chess by virtue of irrelevance (The propositions of exponential decrease are not shared in propositions on playing chess). Thus the structural domain needs to take into account the compatibility[100] of the set of propositions contained within the structural domain to maintain relevance.

Further as increasing a new face increases this excess by one E-V=F-1 or for polyhedra V-E+F=1. He further argues that the premises are not based on any *à posteriori* reasoning.

[100]Two propositions are compatible if they address the same domain.

Box 1 *Illustration of structural and functional domain and the adequacy and relevance of the structural domain using a hypothetical tool.*

Structural Domain

The pieces on a chess board decrease exponentially as the game proceeds.

The pawns move a step at a time.

The rooks can only move parallel to the edges.

The bishops can only move parallel to the diagonals.

The knights can only move to the left or right of a position two squares in a direction parallel to the edges.

The queen can move parallel to the edges or parallel to the diagonals.

The king can move parallel to the edges or parallel to the diagonals one square at a time.

Functional Domain

There are less than 16 pieces in 30 minutes therefore the half life of the game is 30 minutes.

A game finishes faster if the half life is decreased etc.

Criticism

The tool is irrelevant as no primary proposition (upstream of the structural domain) of the first proposition in the structural domain is shared with any primary proposition of the other propositions in the structural domain.

The tool is inadequate by virtue of irrelevance.

The tool is inadequate to decide appropriate strategies to play chess.

The tool is inadequate to study the dynamics of chess pieces.

Addressing Criticism

The tool can be revised by dropping proposition one from the structural domain to resolve irrelevance. Alternately the other propositions can be dropped.

The tool can be made adequate for a task (for example to design appropriate strategies for chess) only by first ensuring relevance. Subsequently it must be possible to derive the desired propositions in the functional domain through the propositions included in the structural domain. For example it should be possible to derive strategies from the structural domain. This is done by adding and revising the propositions in the structural domain. For example unless propositions about alternating moves exist, it is impossible to derive strategies.

Examples of tools which have relevance include the atomic theory and Euclidean geometry. They are thus *adequate to operate on the domain they operate on*. They may naturally be inadequate to operate on other domains. The atomic theory can be considered an example of a search for a structural domain that can map on the functional domain of all elements. It opened up a whole spectrum of new observations of combinations of elements, unknown before its formulation (See Box 1 on p. 16).

Adequacy of a tool can also be questioned if the structural domain can not (or does not) map on to a desired *functional* domain. This is simply because the user encounters a functional domain he wishes to operate upon, but by virtue of the failure of the tool to map on it, the tool is inadequate. This criticism is more difficult to address as this implies a search for a new structural domain that maps to the desired functional domain. This can be contrasted to addressing the criticism on structural domain and characteristics of mapping by revising the existing structural domain.

Chapter 2

Tools for Change

Change

The inhabitants of every society in every civilisation have seen change. Some whose perspective has been their lives, have seen personal change. Others whose perspective has been longer, have variously seen the change of their community, their society, their civilisation and perhaps the whole of mankind. Some even see change beyond mankind. On the other hand those whose interest has been in phenomena which are fast relative to their own personal 'clocks', have visualised change of bacteria, molecules and even atoms.

Change is characterised by events[101]. An event is an happening that falls out of the 'normal' pattern of the observer. An event happens in a particular place. Those who know[102] of an event can recognise *change*. Change is brought about by the acts of the participants who are often aided by the tools they use. The domain of change is not defined by any one discipline. Change is a characteristic of everything in the world.

History points out that every civilisation has spared no effort to understand, communicate or manage change. The things of change that mattered may have been different, but the concern was the same. It could perhaps be said that this central concern was and is often motivated by the need to sustain[103] what is 'normal' or desired order.

When it seems impossible to sustain this normal or desired order, a crisis of unsustainability can be declared. Thus in the management of change, sustainability is the central concern especially in times when unsustainability is apparent. From the individual and enterprise to the inter-national and global levels sustainability is about sustaining the functional 'order' or the system at the level of concern.

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[101] An event is a happening that falls out of the "normal" pattern of the observer. An event is thus something relative to the observer. Events evoke a response of some kind. Thus while sun rising is an "event" to somebody watching the darkness of the night, it is not an "event" to somebody who is in a windowless room when the sun rises. An event is necessarily a "process" that lasts over a duration. It can be recognised only when it lasts at least as long as the duration that the observer samples for its occurrence.

[102] It is possible to know of the event only if one can *recognise* it. Further the observer can only recognise events near him unless he receives information about these events.

[103] The word sustainable comes from the Latin verb *sus-tenere* meaning to uphold. This in turn is derived from the Greek verb *tenein* (τενειν) meaning to stretch. This Greek verb also means to carry the weight of something by support from below. While the colloquial treatment or operational meaning of the concept of sustainability varies widely, the basic meaning of sustainable as *upholding something in time* remains universal (Vries, H. J. .M., de, *Sustainable Resource Use: An enquiry into modelling and planning*, Rijksuniversiteit Groningen, Groningen, 1989, p. 17).

Operationally sustainability means many things to different people or different things to the same people in different contexts[104]. What is important is that irrespective of the level of concern *sustainability implies sustaining the normal or desired order at that level*[105].

The central concern in an idea of sustainability is about the *tomorrow's* to come. Where tomorrow's are immaterial, sustainability would not matter. It is ironical that the unsustainability of the *time* itself is central to the belief of sustaining something for the future[106]. What is clear however is that the belief in time is deep rooted in the concept of sustainability[107].

Whatever the *armchair* musings behind the concept of sustainability, many people all across the world have spent long hours expressing concern about sustainability. The long preparations for the UNCED conference held at Rio[108] in June 1992 and the long list of dignitaries from every corner of the world make it evident that sustainability plays an important role at the national, inter-national and global levels. New management strategies in the form of new legislation, treaties, bilateral agreements seek to express intent of creating a sustainable unit. Strategic planning at enterprise levels also express the explicit intent of sustaining the enterprise. In fact the very essence of management is to use tools to counter the natural change process with the implicit goal of sustaining what is being managed.

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[104] At the individual level the operational concept of sustainability may be, for instance, food, shelter and water. At the enterprise level it may be cash flows, manpower, technology. At the national or international level it may be variously defined as by the Brundtland Commission "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (World Commission on Environment and Development, *Our Common Future*, Oxford University Press, Oxford, 1987) or "The ability to switch to solar based fuels" (Slesser, M., and A. Saraph, *GlobeEcco: A computer model of the developed and the developing world economies; A tool for exploring sustainable development*, Resource Use Institute, Edinburgh, 1991) or as "the duration over which the cycles of the economic engine can continue under preference of life styles of the population" (Saraph, A., and M. Slesser, "Sadi Carnot and Economic Engines" in *Technology Forecasting and Social Change*, 46:3, (*in press*)).

[105] Thus the *bottom line* of sustainability is upholding or ensuring the existence of the unit to be sustained.

[106] Something is sustained differently for one whom time ambles from for him whom time trots. Shakespeare (*As you like it*, III:2:328) puts it well when he says "Time travels in diverse paces with diverse persons. I'll tell you who Time ambles withal, who Time trots withal, who Time gallops withal, and who he stands withal."!

[107] It is perhaps Aristotle who first regarded time as fundamental as he insisted that "there are real comings-to-being and that the world has a basic temporal structure" (*see* Withrow, G., *The Natural Philosophy of Time,* Oxford University Press, London, New York, 1980, p. 1).

[108] It may also be noted that the very existence of a World Commission on Environment and Development is indicative enough about the concern for global sustainability. This commission voiced its concern on global sustainability in its report: World Commission on Environment and Development, *Our Common Future*, Oxford University Press, Oxford, 1987.

The broad alternatives resorted to in order to manage change and sustainability include the tools of management sciences[109], problem solving[110] tools, the tools of knowledge[111] systems and tools of systems[112] sciences. From observations at any level (individual, institutional, national or global) it is clear that the management of change and therefore sustainability seems illusive or at best transient[113]. It is therefore important to examine the broad categories of tools, mentioned above, for relevance[114] and adequacy[115] to operate on change and sustainability. Insights in the irrelevance (if any) or inadequacy of these tools can enable us to design new tools to address the domain of change and therefore of sustainability more adequately.

Management Sciences

As used in the management sciences "change" usually denotes planned change introduced into an institution[116]. It is clear (and also pointed out by some management scientists) that this is only a special case of change. Change takes place irrespective of whether institutions plan for it.

Institutions are themselves a special case of organisations: they are organisations of people. The propositions of change dealing with institutions therefore restrict the scope of the tools for the management change of institutions (for example organisational theories) to the management of people. Such tools are clearly inadequate to manage change in non-human organisations (e.g. humans in an automobile , humans in a forest etc.).

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[109] ✋Every actor☝ by the acts of modifying something is a manager. Management science and business communities generally consider only the special case where the manager is someone who oversees other actors.

[110] ✋Problems are event☝(s) not desired by someone or something. The undesired event(s) are sometimes referred to as symptoms. Problem solving thus involves avoiding or removing the undesired event(s).

[111] ✋As used here, knowledge is simply a set of propositions☝ about the world. Knowledge systems are systems that try to capture the propositions of the world.

[112] ✋The general concept☝ of a system is that of a functional unit of reality. Systems sciences design and apply the tools that address functional units rather than material units.

[113] The story of Nassiruddin Mullah as quoted in the *Groping in the Dark* (Meadows, D. H., J. Richardson, and G. Bruckmann, *Groping in the Dark*, Wiley and Sons, New York, 1982) illustrates the natural resort to tools that one is familiar with to address a domain rather than examine its relevance or adequacy. Returning from a late party Nassiruddin lost the key to his house in the darkness of the night near the door. Noticing the street lamp, he began his search for the key there. On being asked why he was searching there he replied that that was where the light was!

[114] ✋A tool☝ has relevance if all secondary propositions☝ in its structural domain☝ (if any) are relevant in the tool. A secondary proposition is relevant in a tool, if it can be derived from a set of primary propositions which can be demonstrated to be shared with the structural domain of the tool. It follows that if all the propositions in the structural domain are primary propositions, the tool has relevance

[115] ✋A tool☝ is said to be adequate if its structural☝ domain☝ contains only primary propositions☝ and can map the desired functional☝ domain

[116] Armstrong, P., and C. Dawson, *People in Organisations*, Elm Publications, Cambs, 1985, p. 326, Burnes, B., *Managing Change*, Pitman, London, 1992, p. 150.

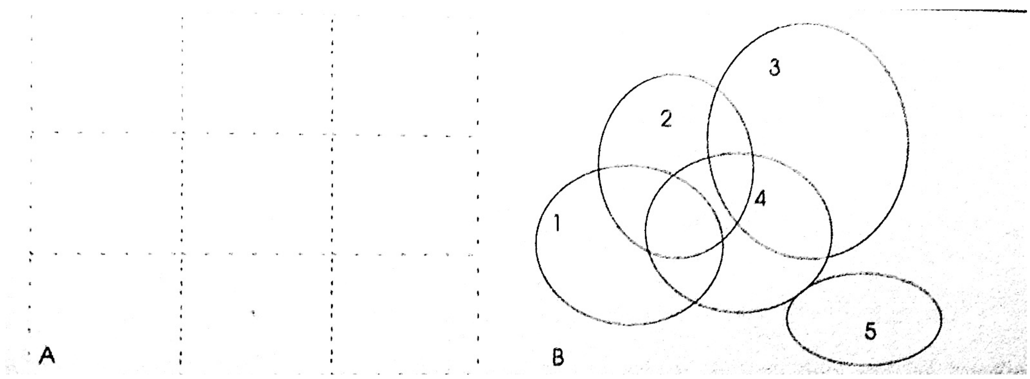

Figure 4 *Division of reality into manageable parts.* ***A****. A perspective from the tool of disciplines and* ***B****. A perspective from the tool of systems: 1-5 are systems containing functionally inter-connected elements.*

Generally the tools of management sciences to manage change are targeted at the individual, group, inter-group or total institutional levels[117]. The tools (which range from career planning, role analysis, counselling, T groups, organisational development, team building, peace-making, quality circles, feedback, process consultation, confrontation, culture change and strategic plans) all rely on change through observationally an observer or overseer[118]. Unless principles of observation are carefully understood there is no guarantee that relevant observation for effecting change can take place.

The tools of management sciences therefore restrict their scope to planned change and human institutions. They are therefore inadequate to examine natural change and sustainability and change in systems that stretch beyond pure human institutions.

Problem Solving

The disciplines of traditional science: biology, physics, chemistry etc. also allow us to handle reality one piece at a time. They allow us to understand, communicate and manage parts of the real world based on the characteristic of their systems. So long as these are (treated as) isolated systems we have reasonable abilities to understand, communicate or manage their change. Unfortunately the real world is not a collection of compartmentalised systems; it is more like a collection of several interacting functional units (See Figure 4). Our abilities to deal with the real world within the scope of any single discipline is therefore limited. There is thus little doubt that these disciplines by themselves are inadequate to address the functional domain of our interest. We have noted the importance for civilisations in enhancing their abilities to handle change. It is thus no surprise that alternative tools have emerged to address the domain of systems.

[117]Burnes, B., *Managing Change*, Pitman, London, 1992, p. 176.

[118]This is precisely why the model of the manager in management sciences is that of an supervisor over other people.

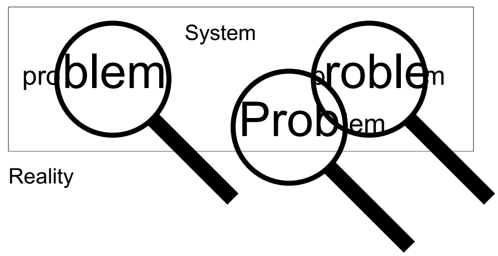

Figure 5 *Systems tools creating a view of a system through a problem lens (each problem defines a system) contrasted with a systems tool creating a view a system as existing in its own right (the box bounding the system from the rest of the world).*

The concept of systems can be viewed as a tool to partition reality into functional units of manageable size. Systems then can be regarded as existing in their own right or they can be considered to be defined by the problem at hand[119] (See Figure 5).

A closer look at problems points out that problems are not absolutes but are a relative concept. Thus problems are problems for an observer in a particular setting[120]. If the observer or the setting[121] changes, old problems could very well be considered solutions or at least not problems any longer. As an trivial illustration consider the value of a key. For a person in a locked room the loss of a key is a problem. In a opened room the loss of the key is generally not a problem and in a room without locks keys have no meaning. An emphasis on the key in all three ‘settings’ is not correct or of any value[122]. If the person is repeatedly moved from setting to setting (which can be regarded as moving from system to system if one allows the system to exist independent of problems) the key becomes relevant at some time and irrelevant at others. Unless the person can recognise having been moved (or the system around having changed) the key may get too much or too little importance. The

[119]Sterman, J., “A Skeptic’s Guide to Computer Models” in Grant, L., ed., Foresight and *National Decisions*, University Press of America, Lanham MD, 1988, p. 133-169.

[120]A setting is regarded as a system if systems are granted existence in their own right.

[121]With reference to settings, it is interesting to note the classification of the “complexity dimension” by de Vries (Vries, H. J. M., de, “Trends and discontinuities: their relevance for sustainable development strategies” in Dutch Committee for Long Term Environmental Policy, *The Environment: Towards a Sustainable Future*, Kluwer Academic Publishers, Dordrecht, 1993, table 2., p. 282). He views the world as consisting of an geosphere, ecosphere, technosphere and sociosphere. Each of these spheres corresponds to Daly’s classification of ultimate means, intermediate means, intermediate ends and ultimate ends (See Daly, H., ed., *Toward a Steady State Economy*, W. H. Freeman and Co., San Fransisco, 1973, p. 8). de Vries points out that the perceived relation of humans to the “sphere” dictates both their modelling perspective and response strategies at each level. Thus for viewing themselves as the participant and creator of the sociosphere mans approach to modelling is actor oriented and response strategies are cultural or lifestyle changes in contrast to their strategy of adaptation and restoration in the ecosphere.

[122]Lewis Caroll in his *Alice in Wonderland* points this out rather well. The key to open the door is of no meaning to Alice when she is too big to pass through the door. On the other hand it is difficult for her to get at the key when she shrinks in size!

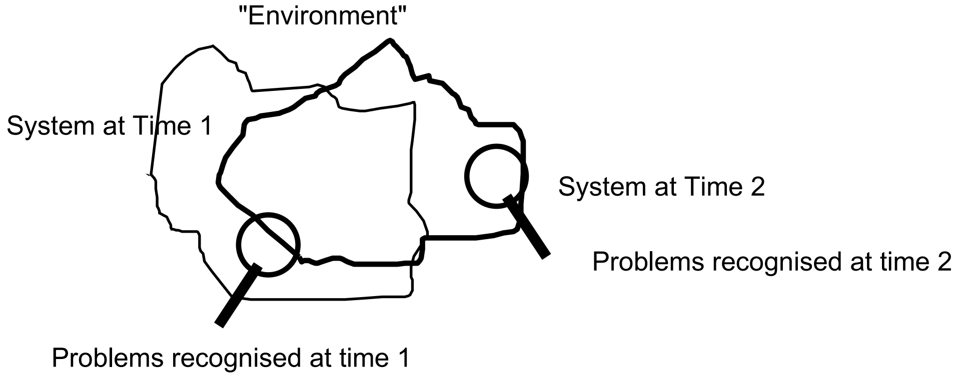

Figure 6 *Problems as moving targets: problems that are recognised at different stages can be different but so can the system itself!*

participants in the real world experience systems in precisely this fashion. This is analogous to viewing that the system undergoes a constant change. Thus managing problems is like managing a moving target in a system that is undergoing constant change (See Figure 6).

Problems are thus shifting with a system. As the system itself changes constantly solving the problems of the system can only lead to a problem-solution sequence[123] in the form of a self perpetuating spiral. Problem solving thus only displaces the problems to a different place or different time. As the sustainability of the system of interest is central to the management of change, it is important to explore how a problem solving approach works for the sustenance of a system. If (un)sustainability is viewed as a problem, then following the problem solution spiral, it is inevitable that what is (un)sustainable now could be otherwise later[124]. Like all problems, we would be managing a moving target and constantly moving through problem-solution spirals (See Figure 7 on p. 25).

It is clear from the history of civilisations that unsustainability has been a problem of several civilisations before ours[125]. The relics of these civilisations imply they did indeed have some tools of problem solving. While it cannot be conclusively said that the problem solving did not help these

[123]While the specific problems may be new it is the sequence which is repetitive. It is perhaps this very sequence that has been referred to as the “chakravyuha” in ancient Indian literature. This literature talks about the ease of getting into this spiral and the difficulty of getting out. It is also interesting to note George Orwells *Animal Farm* where he points out the futility of managing change through replacement of *actors* or *practices* if the system remains the same.

[124]It is perhaps precisely this reason that de Vries concludes that sustainability is a declaration rather than a definition. (Vries, H. J. .M., de, *Sustainable Resource Use: An enquiry into modelling and planning*, Rijksuniversiteit Groningen, Groningen, 1989, p. 68-69)

[125]See for example Girardet, H., *Earthrise: How we can heal our injured planet*, Paladin, London, 1992, p. 12 and Ponting, C., *A Green History of the World*, Penguin Books, London, 1991.

civilisations, it can certainly be asserted that *the tools*[126] *of problem solving were inadequate to sustain these civilisations*.

For another illustration, consider the traditional agricultural practices of the people of Punjab in India. These practices were imagined as being unable to sustain the population. In the sixties the 'Green Revolution'[127] was introduced. The new practices of the process were imagined to enable sustaining the population. The resultant boom in production per hectare of land in the seventies was seen as an achievement of a sustainable solution.

Social disruption due to the widening of the gap between the poor and the rich, the landless and the landowners became apparent in the eighties. Today Punjab remains one of the socially and economically troubled parts of India. Environmental problems due to intensive agricultural practices are also apparent. It is clear that the traditional agricultural practices may have been more sustainable for the community and the environment.

To take a simpler trivial example, the warmth in a cold room is sustained, for the rooms inhabitants, at the cost of heating it. When the attention moves to the fuel, the fuel is sustained if it is used at the rate of replenishment. So long as some unsustainable process has the attention, the issue at hand is the *problem* of the unsustainable practice(s).

Usually the recognition of unsustainability results in effort to remove or replace the unsustainable process. This can result in quick corrections to the *process* under consideration and "buy" time but have little concern for the system as a whole. Using the problem solving tools at hand, maintaining or moving towards overall sustainability is thus an impossible target as there is little that can be done in order to sustain the *system* with these tools.

Problem solving tools can not ensure their relevance. The structural domain of such tools can collect propositions that do not share any common primary proposition. This is precisely because the tools of problem solving do not evaluate the propositions they collect. Thus problem solving tools can also be considered to contain *à posteriori* propositions in its structural domain (the problem definition) which can eventually be questioned. Even if it is not questioned, being a secondary proposition it does not contain propositions that will allow to distinguish when the proposition (problem) is relevant and when not. Thus problem solving is inadequate for the management of change and therefore sustainability.

Knowledge and Information[128] Systems

It has been recognised that change can be noted through the occurrence of events. Since it is possible to know of change if we can have information about events, no attempts are spared in devising event acquisition systems and classifying and storing every proposition that can be noted to explore them for events. Thus there is every effort to capture all the possible propositions on the real world that

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[126]Institutions can also be considered as tools.

[127]High yielding crop varieties that require high input farming techniques (more fertiliser, water, pesticide etc.) replace traditional 'low yielding' varieties in the so called 'Green Revolution'.

[128]Information is available knowledge. Information is thus relative to an actor and depends on the actors ability to recognise the knowledge. The use of this word is to be avoided unless referring to the availability of knowledge.

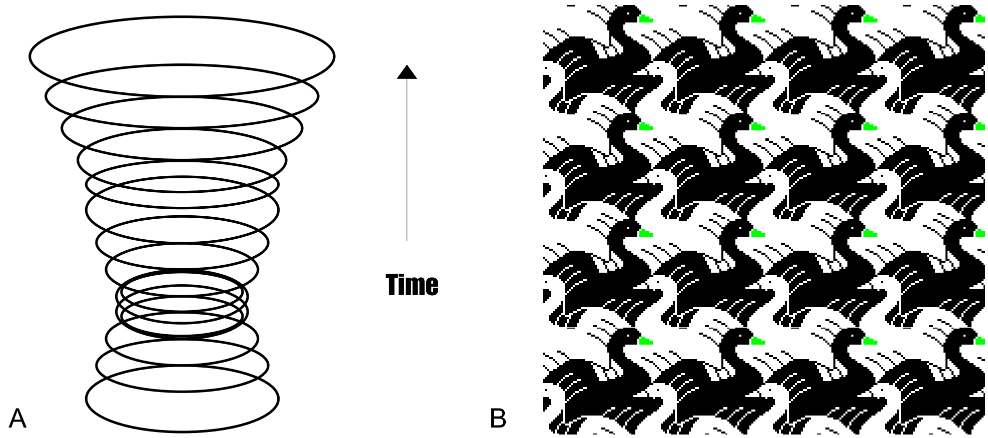

***Figure** 7 **A**. Problem-Solution spiral **B**. as viewed through the eyes of Escher. There is an ever continuation of the pattern in both A and B.*

can ever exist. The enormous databases, accounting systems, highly specialised fields indicate just this.

Intuitively we know the impossibility of this task, but for argument, let us imagine a device, a knowledge demon, that is able to keep track of all the propositions of the world[129]. We can assume that such a device would be able to know the world completely as it tracks every proposition[130]. One can assume that such a device will not have any problem managing the world on the grounds that it knows change (which is described by a set of propositions) and can then manage it. However any 'lesser' devices, limited by the happenings they can track, will need to evolve strategies to overcome their inherent limitation to knowing. The mind being a part of the world can know only a part of the world. Therefore it faces the question like any device which can capture only part of the propositions, of how relevance about our knowledge can be maintained irrespective of our inability to know the world completely.

[129]This is similar to Maxwell's famous demon which kept track of the high and low energy particles and partitioned them. Maxwell used the demon to show the impossibility of cold bodies turning hot spontaneously.

[130]In practice simple recursion shows that such a device is impossible. Such a device would need to track its own tracking, etc. Thus making it impossible for almost the same reasons that infinity cannot be approached.

Whatever the real world may be, each of us ‘maps’[131] propositions[132] of the world as concepts stored in the mind. It is these propositions that constitute our understanding of the real world and make it possible to communicate or manage the world. As pointed out in chapter 1, the *relevance* of such understanding is necessarily decided by the ability to establish common primary propositions in the map (tool) and all its secondary propositions[133]. It is obvious that the flaws, accessibility and relevance of such mappings shall contribute to the flaws and relevance of the resultant communication or management through simple inheritance of the characteristics. If relevant management of any kind, not just to sustain the system is to be possible at all, it is important to take a look at the nature of this mapping process.

If we were to develop the idea of mapping, mentioned above, further, then a simple mathematical calculation can point out to the limit of the propositions to be stored in the human mind. Let us consider that the human mind has n ‘accumulators’ to store what it monitors. Let us assume it ‘consumes’ m accumulators as its overhead[134] to monitor the accumulators themselves. It can then be concluded that $(n\text{-}m)!$[135] is the number of possible *states* of the world that can be recognised [136] if each accumulator can store a single proposition which has binary states (see Figure 8).

[131] Mapping is establishing a correspondence between two objects. The idea that the human mind maps the real world is not new. In fact Schrödinger argued that it can not be otherwise when justifying that laws of nature do indeed exist: “The working of an organism requires exact physical laws...The reason for this is, what we call thought (1) is itself an orderly thing, and (2) can only be applied to material, i.e. to perceptions or experiences, which have a certain degree of orderliness. This has two consequences. First, a physical organisation, to be in close correspondence with thought (as my brain is with my thought) must be a very well ordered organisation, and that means that the events that happen within it must obey physical laws, at least to a very high degree of accuracy. Secondly, the physical impressions made upon that physically well-organised system by other bodies from outside, obviously correspond to the perception and experience of the corresponding thought, forming its material, as I have called it. Therefore the physical interactions between our system and others must, as a rule, themselves posses certain degree of physical orderliness, that is to say, they too must obey strict physical laws to a certain degree of accuracy.” (Schrödinger, E., *What is Life? The Physical Aspect of the Living Cell*, Cambridge University Press, Cambridge, 1945, p. 7-8).

[132] Propositions are statements about the real world that describe facts or relationships. Compound statements are referred to as secondary propositions or theorems. Simple statements that cannot be further reduced are referred to as primary propositions.

[133] de Zeeuw points out that “knowing more about some part of the world, even if that part concerns the use of such knowing, apparently does not imply knowing more about the effective use of this type of knowing” (Zeeuw, G., de, “The actor as a perfect citizen” in Stowell, F., D. West, J. Howell, eds., *Systems Science: Addressing Global Issues*, Plenum Press, New York, 1993). This raises yet another dimension in the use of knowledge systems.

[134] Overhead is the use of the something in order to make possible its own use. For example the memory used in the computer to keep track of the files on the computer is an overhead. This memory then is unavailable to do the tasks that you want the computer to do. In this context it is the use of accumulators themselves to allow their use.

[135] (n-m) *factorial* or the number of permutations that are possible in a binary logic for propositions.

[136] It is interesting to note that the sampling rate of the human sense organs is itself regulated, perhaps to buffer the mind from receiving too many impressions. Hughlings Jackson has, for example, drawn attention to “time in the form of some minimum duration is required for consciousness” and high speeds of neural

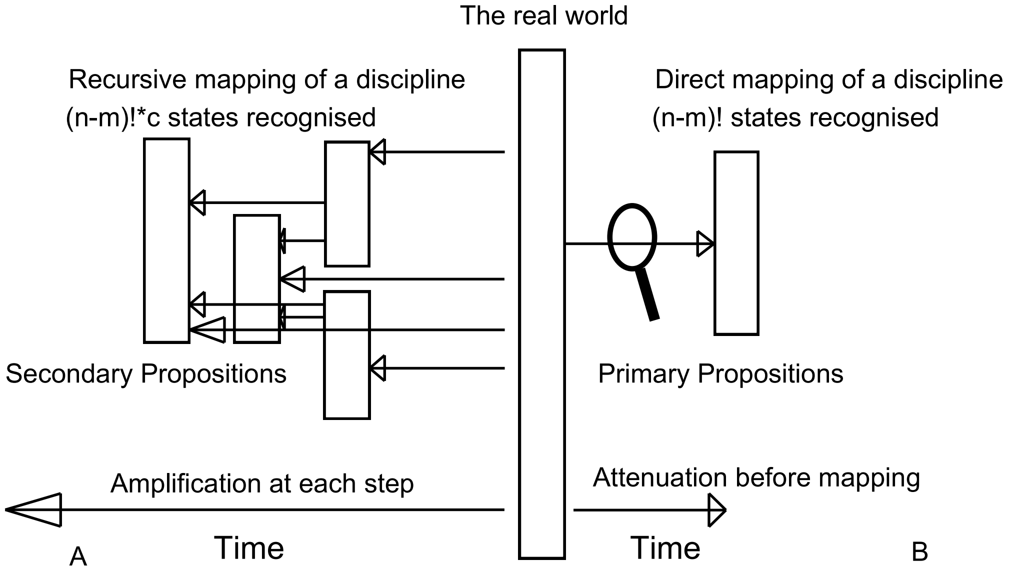

Figure 8 *Mapping of the real world: In 'A' there is no attenuation mechanism and amplification takes place when every new 'fact' based on earlier facts and some direct mapping takes place. Thus with time, as amplification grows, reality gets further away. Such tools are unlikely to guarantee relevance. They are also likely to be inadequate by virtue of irrelevance or due to the secondary propositions they contain. In 'B' there is no amplification but attenuation as all empirical facts stem from this direct mapping alone and there is an explicit search for mechanisms to replace the need to map empirical facts. With time the distance may decrease as simpler propositions are further simplified to primary propositions. Such tools ensure relevance and can be adequate to operate on their defined domains.*

This means that if new states of the world need to be recognised, there has to be a possibility to *rewrite* some of the old accumulators[137]. Alternately ways need to be found to manage the (n-m)! limit. If rewriting part of the accumulators were the only mechanism open to us then we can hope to map or capture only parts of the world. Thus a more 'fuller' knowledge of the world is permanently denied to us. It gives little hope for a more wider understanding of the state of things. On the other hand at least two broad possibilities to rewriting exist to enable the management of the (n-m) available accumulators.

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discharge are known to cause disorders like epileptic seizure (Withrow, G., *The Natural Philosophy of Time,* Oxford University Press, London, New York, 1980, p. 73-74). The minimum duration of visual experience, defined in terms of the rate at which successive presentations lasting 0.06 seconds of static images is seen as an apparent movement, is 16-18 per second. The auditory experience also recognised at 16-18 cycles per second. Similarly we cannot distinguish tactile impressions faster than 18 cycles per second.

[137]This is possibly why forgetting is as important, if not more, than learning.

The first of the two management strategies searches for *economy* of knowledge[138]. Thus there is a criteria to *attenuate*[139] facts and observations before storage. This involves the storage of primary propositions about reality and laws that through processing can derive (almost) all possibilities not individually collected and stored. Through continuous reframing the frames we seek the "simplest possible system[140] of thought which will bind together the observed facts"[141]. This search for this simplest system is expected to be closer to the 'truth'[142]. The big advantage of such a system is that the relevance of all propositions can be established directly as there is a single frame. Observations of the real world described by such frames point to states of the frame and make conditional forecasts of change possible. Access to facts is limited by the access to the frame itself.

The other alternative sets to generate *coding*[143] systems for all information collected. Information stored onto secondary storage devices, like computers, is a typical example of coding[144]. Coding is also possible by distribution of parts of reality to different minds for storage. This typically means specialisation in a domain, for example in molecular biology. The specialists gain expertise in their domains and address special *problems*. The collective then constitutes the store of 'understanding' of the real world. In our simple mapping system described above, let us introduce an ability for the mind to code information. If the coding factor[145] is c, then we have the new possibility (n-m)!*c to store facts[146]!

[138]The number of facts reported together in all natural sciences was estimated to be over one million per year in 1958. Gauging the exponential increase of scientific facts in this century, it is easy to see the phenomenal number of facts that will have accumulated at the turn of the century. (Pauling, L., "The significance of chemistry" in Hutchings, E., Jr., ed., Frontiers *in Science: A Survey*, New York, 1958, p. 279).

[139]Attenuation is compression through selection.

[140]System as interpreted here is analogous to a frame or theory. By "simplest possible system" Einstein refers to one that "has no mutually dependent axioms" (Einstein, A., *Essays in Science*, Philosophical Library, New York, 1934, p. 113).

[141]*ibid.*, p. 113.

[142]This is sometimes referred to as truth approximation. The problem of truth approximation is often visualised as minimising the symmetric difference between the theory *A* and empirical observations *X* (see for example Kuipers, T., "Naive and Refined Truth Approximation" in *Synthese* 93:299-341, 1992).

[143]Coding is a process where propositions are expressed in a specialised 'language' of a target system for storage, reading, writing, retrieval and inferencing.

[144]Facts are always coded into the 'language' of the device(s) or system(s) of secondary representation before they can be stored, read, written or retrieved.

[145]The coding factor can simplisticly be viewed as partitioning, assuming every partition to have *n* accumulators. Thus if 10 specialisation's were developed or 10 new secondary storage systems were introduced, they correspond to partitioning the propositions across 10 *secondary* accumulator clusters. Thus *c* is then 10.

[146]It is relevant to note Poppers observation on the collection of observations: "The collection of observations corresponds to the 'Baconian myth' that all Science starts from observation and then slowly and cautiously proceeds to theories" (Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 137).

Such coding mechanisms while increasing the storage capacity need larger access-times[147] than before. A closer look can make obvious that longer times to seek information are not the only constraint such systems introduce. Since coding is often catalogued or based on 'problem domains' there is accumulation of facts relevant to only the small domain of a problem. Thus they generate a need for evermore coding than before, increasing the access-times even more. Perhaps more importantly, since the domain is not necessarily contained (or expressed) in the proposition as it is stored, the relevance of the proposition is lost in many uses of the proposition. Thus if mappings were based on other mappings, relevance would be restricted to the *n* ary mapping. and cannot be universal relevance[148].

Perhaps the most ironical of all is the *amplification*[149] of facts by the process of codification itself. This is simply a consequence of empirical observations serving to generate newer 'empirical' data. For example studies based on other studies or data generated from other data illustrate the recursive amplification of information[150]. Every new proposition based on previous propositions increases the number of propositions that exist. Each step of an intervening mapping is a definite amplifier. Such tools are likely to be *irrelevant* as they contain propositions that originate in different tools and do not necessarily have any shared primary proposition.

The act of managing, as we observed, implicitly tries to sustain the system being managed or sometimes to create a system to be sustained. The tools of management attempt to intervene in the natural process of change. Our tools decide the nature of our intervention, and thus output. With hammers we can nail objects. With microscopes we can observe the microscopic world. With the tools for understanding or managing the real world we decide what we can do to the real world. If our tools of obtaining knowledge cannot be accessed in time or determine the relevance of the knowledge they generate then we can hardly hope that our actions on the world have any meaning.

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[147] Access time is the time to retrieve a proposition of interest. Typically access time comprises of a seek time (or the time to seek the partition that has the proposition of interest), search time (to search the proposition of interest) and read time (or the time to read or infer the proposition of interest).

[148] In such a case the inference through the propositions stored can be correct but untrue. If some propositions based on other propositions form the basis of an argument, *A,* then the basis of establishing relevance is lost because there is no method to ensure that the complete set of propositions are included in *A*. To illustrate with a trivial example, the journalists know from observation that when the chancellor travels left he will see the Governor of the Bank and negotiate a lowering of the interest rates. They also know that when he travels right he will see the finance secretary to advise the investments as interest rates are likely to go up. The conclusion that as the chancellor went right, the interest rates will go up may be true, but its correctness is uncertain. There is no way to establish that all propositions (for example if the chancellor could turn left after a short ride to the right) are included.

[149] It should be noted that Beer has also voiced strong concerns about amplification for a long time. His concern has followed from Ashby's "law of requisite variety" which necessitates that variety (or number of possible states) from one system equals variety from another for management. Thus it is impossible to manage a system whose variety is higher, unless its variety can be attenuated or the managing systems variety can be amplified. He argues that we in fact amplify the variety of the system we wish to manage and attenuate our variety (See Beer, S., *Platform for Change*, John Wiley and Sons, London, 1975 and Beer, S., *Designing Freedom*, John Wiley, London, 1975).

[150] This strategy is perhaps the most commonly practised strategy to manage knowledge today.

With the *adequacy* of knowledge systems in question, sustainability can become an impossible target.

Systems Science

Probably the earliest *tools for systems*[151] were bookkeeping devices[152]. In current times professions devoted to modern day use of the tools are common. It is standard practice for individuals to keep records of their resources in at least a semi-formal form. It is standard for any institution or business enterprise to keep track of their transactions in a formal way, almost forced by law to do so. The nation state itself uses the records of the institutions within and its own records to keep track of transactions with other nation states. It is not unusual to find international organisations engaged in keeping track of their transactions through bookkeeping too (see Table 1 on p. 31).

Such bookkeeping tools *implicitly* demarcate a system of interest. Different bookkeepers or even the same bookkeepers at different times implicitly draw different system boundaries. The domain they act on, the system, is therefore different at different times or depending on who draws the boundary. The bookkeeping tool sheds little light on what the relationships within the system are. Its concern is to map the events, of interest to the bookkeeper, within the system. The structural domain of the bookkeeping tool does not map on to a functional domain of relationships and therefore is of little *direct* help to answer 'what if' questions. It is no surprise therefore that a whole range of ancillary tools through the modification of the structural domain of bookkeeping in the form of cost benefit analysis, cost-effectiveness analysis, preventive expenditure analysis, replacement cost analysis[153] etc. evolved in order that the bookkeepers records can be used for 'what if' analysis. These tools in general rely only on *à posteriori* inputs (in the form of the bookkeeping records). These therefore suffer from not only restricting the scope of the functional domain but also from inability to establish relevance of the propositions. They are therefore inadequate for the task at hand.

Perhaps it was Bertalanffy who first conceived the first formal definitions of systems in early 1920's following the consideration of an organism as a whole or a system[154]. He identified systems as *real* systems "that is entities perceived from observation, and existing independently of the observer" and *conceptual* systems "which are essentially symbolic constructs"[155]. He further proposed that

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[151]Tools *for* systems are tools that allow to view the real world as functional units and operate on such functional units.

[152]Books on Resource Economics exist as far back as 2300 years ago (see for example a Marathi translation of the original Sanskrit document in Chanakya, A., *Kautilya Arthashastra,* Varada Books, Poona, 1990 which refers to several centuries of work in Resource Economics). The principles in these books clearly take into account the need for keeping track of resources of the nation state and therefore point towards the existence of means of bookkeeping.

[153]See a standard text on economics or econometrics for details on such tools. For example Samuelson, P., *Economics*, McGraw Hill Book Company, New York, 1973. A detailed description of some of these tools and their application to environmental problems is given in Winpenny, J. T., *Values for the Environment: A Guide to Economic Appraisal*, HMSO, London, 1991.

[154]Bertalanffy, L., *General System Theory*, George Braziller, New York, 1969, p. 7, 12.

[155]*ibid.*, p. xxi.

Table 1 *An example of current bookkeeping from the World Bank data tables showing current account balance excluding official transfers for Asian countries (in US $).*

	1980	1981	1982	1983	1984	1985	1986
Bangladesh	-8.434E+08	-8.440E+08	-8.946E+08	-3.779E+08	-2.391E+08	-6.135E+08	-1.214E+08
Bhutan	..	..	..	-2.860E+07	-2.820E+07	-2.590E+07	-2.280E+07
China	9.000E+08	3.131E+09	6.466E+09	4.804E+09	2.983E+09	-1.132E+10	-7.733E+09
India	-2.267E+09	-2.989E+09	-2.647E+09	-2.640E+09	-2.944E+09	-5.535E+09	-5.588E+09
Indonesia	3.010E+09	-5.659E+08	-5.323E+09	-6.337E+09	-1.855E+09	-1.922E+09	-3.910E+09
Korea	-5.320E+09	-4.645E+09	-2.649E+09	-1.605E+09	-1.371E+09	-8.869E+08	4.617E+09
Malaysia	-2.847E+08	-2.485E+09	-3.600E+09	-3.496E+09	-1.671E+09	-6.129E+08	-1.227E+08
Nepal	-2.940E+07	-2.450E+07	-4.890E+07	-1.408E+08	-1.098E+08	-1.040E+08	-1.266E+08
Pakistan	-8.684E+08	-7.493E+08	-1.116E+09	-1.778E+08	-6.888E+08	-1.282E+09	-7.734E+08
Philippines	-1.902E+09	-2.060E+09	-3.199E+09	-2.770E+09	-1.293E+09	-3.490E+07	9.540E+08
Sri Lanka	-6.552E+08	-4.443E+08	-5.482E+08	-4.659E+08	9.000E+05	-4.183E+08	-4.170E+08
Thailand	-2.070E+09	-2.569E+09	-1.003E+09	-2.873E+09	-2.109E+09	-1.537E+09	2.472E+08

science as an abstracted system is a part of conceptual systems such as logic and mathematics that correspond to reality.

Since this early insight, the propositions defining of the concept of systems became less specific and more arbitrary. Bertalanffy himself defines a system as “a set of elements standing in inter-relations”. He defines inter-relations as “element *p*, stands in relations, *R*, so that the behaviour of an element *p* in *R* is different from its behaviour in another relation, *R′* ”[156]. What is clearly missing from this definition is a means of deciding[157] and justifying[158] which elements become part of the system and which do not. This leads to inconsistent propositions about systems simply because the “same” system structural domain maps to the same functional domain with contradictions.

Ashby has undertaken another route. He uses “machine” as a synonym to system and defines anything which behaves in a machine-like way, namely, “that its internal state, and the state of its surroundings, defines uniquely the next state it will go to”[159] as a system. He thus considers a “machine with an input” as a modern definition where “the machine is defined by a set *S* of internal states, a set *I* of input surrounding states, and a mapping, *f* say, of the product set *I*x*S* into *S*”. While this is indeed a more “fundamental” representation in contrast with convenient ones, as claimed by Ashby[160], it provides little help in deciding which states belong to *S* and which to *I* thus allowing a

[156]*ibid.*, p. 55-56.

[157]How do these elements become a part of the system.

[158]Why and when do these elements become a part of the system.

[159]Ashby, W. R., “Principles of Self Organizing System” in von Foerster, H., and G. Zopf, eds., *Principles of Self Organisation*, Pergamon Press, Oxford, 1962, p. 261 and Ashby, W. R., *An Introduction to Cybernetics*, John Wiley and Sons, New York, 1955.

[160]*ibid.*, p. 261.

(*S*+*I*)! machines based on the arbitrary choice of the modeller. Thus a contradictory set of propositions in the functional domain can be generated from the structural domain depending on the choice of the (*S*+*I*) permutation, making the tool inconsistent.

Beer who has been among the well known and long standing practitioners of these concepts defines systems as "anything that consists of parts connected together"[161]. It follows that connections are determined by what the modeller sees rather than any logical criteria. It is obvious that the tool as defined by him suffers the same limitations as his predecessors. Beer has also pursued the study of "how systems are viable"[162] like Miller has explored what are the characteristics of "living systems"[163]. These studies have identified certain necessary characteristics of viability[164] of systems (See Appendix 1 for a simplified re-statement of Beer's Theory). Viability is a secondary proposition. A theory of viability is possible based on more fundamental or primary propositions. Thus while these tools can be adequate, they are potentially subject to the consequences all systems based on secondary propositions have[165].

Forrester defines a system as "a grouping of parts that operate together for a common purpose"[166]. Forrester stresses the importance of the system boundary, pointing out that "any specified behaviour must be produced by a combination of interacting components that lie within the boundary that defines and encloses the system"[167]. However he does not provide any criteria to draw the system boundary. Forrester also provides no criteria to identify the "common purpose" of the system. (For a statement reorganised to expose the structural and functional domain of System Dynamics, see Appendix 2).

System Dynamics maps feedback loops onto "systems". However System Dynamics is inconsistent in mapping the feedback's loops to systems. This inconsistency arises from the fact that two practitioners can identify different "systems" and claim to address an identical "domain". It clearly follows from the structural domain of System Dynamics itself, that the dynamics of a system can change completely when one feedback loop is altered. Practitioners designing a model of the system can include or miss a feedback loop that alters the behavioural profile completely. Also for reasons argued earlier, since the system can be considered to change, tracing feedback's to identify a system is like following a moving target. If practitioners have no way to map the feedback loop onto the

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[161]Beer, S., *Cybernetics and Management*, John Wiley and Sons, Inc., New York, 1964, p. 9.

[162]Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989.

[163]Miller, J., *Living Systems*, McGraw-Hill, New York, 1978.

[164]See for example Beer, S., *Diagnosing the System for Organizations*, John Wiley, London, 1985 and Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989, p. 33-34.

[165]See chapter one, evaluation of tools.

[166]Forrester, J. W., *Principles of Systems*, MIT, Cambridge, 1968, p. 1-1.

[167]*ibid*., p. 4-1, 4-2.

system under study, it is only a consequence that the mapping is inconsistent. The validity of the conclusions based on such inconsistent mappings is automatically in question[168].

We therefore conclude that System Dynamics really addresses principles of *feedback* and not *systems* at all. Thus if System Dynamics were to address the domain of systems it would need to have a different structural domain. This is sufficient to point out that the domain of System Dynamics needs revision *unless* the user of System Dynamics is content with the domain of feedback loops independent of systems which cannot describe what these feedbacks mean to participants and how do events affect such loops.

Examining the feedback loop in System Dynamics, from a need to understand, communicate or manage action, points out that the structural domain of System Dynamics is inadequate. The inadequacy of the structural domain also restricts the functional domain that can be mapped using the tool. The feedback loop in System Dynamics does not consider any participant actors who govern the policy or action stream in the feedback loop. It is obvious that if any conclusions about the participants and their role is to be drawn, they need to be part of the structural domain.

The feedback loop in System Dynamics does not provide for events[169] that constitute part of feedback. As the feedback loop in System dynamics ignores the participants, it cannot value events. The idea of feedback itself is a secondary proposition. This means that simpler propositions can describe the feedback loop itself. If simpler propositions than feedback constitute the structural domain, then the scope of the functional domain is enhanced. By using secondary propositions in the structural domain, we restrict the scope of the functional domain.

Systems are described in System Dynamics as assemblies of interacting feedback loops[170]. While this is the connecting bridge between the idea of feedback and systems in System Dynamics, it gives

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[168]Practitioners address the issue of validity of conclusions on the basis of validation of System Dynamics models (See especially Forrester, J. W., and P. Senge, "Tests for Building Confidence in System Dynamics Models" in Legasto, A., J. W. Forrester, and J. Lyneis, *TIMS Studies in the Management Sciences*, Vol. 14, North Holland Publishing Company, Amsterdam, 1980, p. 209-228). Forrester and Senge claim that validity is not a matter of absolute truth. As pointed out in chapter 1, validity is a characteristic of mapping the propositions in the functional from the propositions in the structural domain such that the conclusions follow from the premises. In this limited meaning of validity the tests to verify model structure by "comparing directly with the structure of the real system" (p. 212) do not examine if the conclusions drawn by the model at all. Additionally if comparing directly was indeed a process of "validation" it will suffer from the same consequences as designing the model itself. Forrester and Senge do not address this important point which has nothing to do with "parameter verification" (p. 212-213), "extreme condition test" (p.213-214), boundary adequacy test" (p. 214-215) which in fact justifies system boundaries through the purpose of the model, "dimensional consistency test" (p. 215-216), "behaviour reproduction tests" (p.217-219) and "behaviour prediction tests" (p.219-220).

[169] An event is a happening that falls out of the "normal" pattern of the observer. An event is thus something relative to the observer. Events evoke a response of some kind. Thus while sun rising is an "event" to somebody watching the darkness of the night, it is not an "event" to somebody who is in a windowless room when the sun rises. An event is necessarily a "process" that lasts over a duration. It can be recognised only when it lasts at least as long as the duration that the observer samples for its occurrence. Thus contrary to feedback representations in System Dynamics, response can be to events and not information about state of the system.

[170] Forrester, J. W., *Principles of Systems*, MIT, Cambridge, 1968, p. 4-6.

no clue to "collect" and group feedbacks. As pointed out earlier, some practitioners simply collect together feedbacks that reproduce the reference behaviour[171]. In fact the starting point of the study of such practitioners is with the reference modes. Knowledge of combination of feedbacks producing a particular behavioural pattern (the generic processes, generic infrastructures described above) usually dictates the "search" for feedback in the real world. The identified and assembled feedbacks become a "system". Other practitioners use "systems analysis" or other techniques to build a list of important elements that are interconnected in what has become a "system" by virtue of grouping together elements of interest. They cannot do otherwise as the structural domain of System dynamics is incomplete in providing propositions to "collect" feedback loops into a system.

It is thus clear that the miscellaneous tools of management sciences, problem solving, knowledge systems and systems science are either irrelevant or inadequate to address the domain of change and therefore sustainability. It is evident, therefore, that the design of new tools is required if one were to operate on the domain of change and therefore sustainability

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[171] Reference behaviour or reference modes are usually historic representations of the behaviour of the problem variables. They thus structure the problem definition. Sometimes "future probable" representations are also called as reference modes (See Anderson, D. F., and G. P. Richardson, "Toward a pedagogy of System Dynamics" in Legasto, A., J. W. Forrester, and J. Lyneis, *TIMS Studies in the Management Sciences*, Vol. 14, North Holland Publishing Company, Amsterdam, 1980, p. 94-95).

Eavesdropping

By some chance we are next doors. Like it so often happens, we hardly know who is next doors. And we hardly know the people who are next doors. How much we could discover if we only could! The thin walls (they use this flimsy material these days, you know; it saved them much money and made eavesdropping easy you hear) drops their conversations onto our (y)ears. Annoying sometimes. But we have only the reactivity to the conversation. Maybe we can just react and burst in about this noise and nonsense. But on the other hand is it? And I thought we were self aware... Wait a minute. Hush! I hear something.

“Say, do you believe in tomorrow’s? I live for now. I definitely hate living in yesterdays like them.”

“What does he mean by this *tomorrow* then?”

“But then you do care about living... That seems precisely what tomorrow is all about!”

“By the way, do you plan to come to the party tomorrow?”

“There we go again....”

“Sure would love to but for this problem. Can I give you a call if I can get rid of it?”

“Rid?”

“Of course! I’ve done that for so long, have I not?”

“What about me?”

“Well, I admit some problems are beyond me, but...”

“Jokes apart, we have moved from the industrial to space to information age, haven’t we?”

“Yes. Anyone would say that is progress. Just ask around!”

“... You think we did these feats without problem solving and knowledge systems?”

“...We’ve even built the pyramids using such tools; perhaps the ‘primitive’ systems tools in the form of bookkeeping? I think he is going overboard about these tools!!”

“But *that* is not being disputed in the argument...”

“He talks about tools *for change*. Everything causes a change and all that.. but how do we actually come to terms with it?”

“...To use his language, ‘operate’ on change itself? All he claims is these tools don’t seem to come up to the requirements to operate on change.”

“Is it really necessary to ‘operate’ on change? I mean is change really that universal?”

“Don’t you know that in the universe everything is in flux, and nothing is at rest[172].”

“Well, I have heard that nothing is constant but change!”

“Then he who does not expect the unexpected will not detect it: for him it will remain undetectable, and unapproachable[173].”

“... so we need tools that can indeed ‘operate’ on change, and since change is of a later time he uses tomorrow in a literal and figurative manner!”

“Yes then if you did rid the problem *me*, you would only have another and another and another..”

“So much for your problem solving lust.”

“Don’t you know spiritual history has revolved in search out of this *chakravyuha*?”

“Ask Zen if they solve problems, will you?”

“Don’t embarrass me. A fellow has to earn a living you know...”

“When you put it so I seem to understand it better. I wonder why he does not say it so clearly!!”

“I may say the organisation managers try their information system to pin me down...”

“And now with all these computerised things!”

“Thank goodness for irrelevance and inadequacy!”

“But don’t you realise that it is precisely the irrelevance and inadequacy that make you feel you need to heave that sigh of relief?”

“They may get down to systems science, but it would not work either.”

“Have you heard the latest news update on the new boundary of the province of Constant-in-hopel?”

“Is that where you need a toolbox?”

“I don’t know.. I can barely use my toolbox to repair the flat tyre on my bike.”

“But this guy seems to have put on a tool lens! And he will probably say that is a tool too?”

“Well, I must kind-of-admit that I like the idea of providing sound methods to trace the premise to conclusion maps for everything.. It gets so muddy these days.”

“Yes. I have been using problem solving tools for so long too. And I must admit the ‘tools’ seem to become calculators with invisible premises and magic conclusions by the dozen.”

“The logic is perfectly logical.”

“Why on earth do you think it’s so?”

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[172]Heraclitus quoted in Popper, K., *Conjectures and Refutations: The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1972, p. 144.

[173]Heraclitus quoted in *ibid.*, p. 147.

“Too many of these x@* observations that we must make sense of. What can you expect? If I do not relate myself to them I must be wrong or imaginary.”

“But then geometry and chemistry must be too?”

“Yes, I almost forgot that the foundations of these tools rest on *no* observation!”

“Of course, like all beautiful tools! But the conclusions are very observable.”

“What would Popper say to Dalton?”

“You are falsified!”

Part Two

Toolbox for Tomorrow

The tools that form part of the toolbox are described here.

Chapter 3

Syslogic

Origins

In part 1 we explored the nature of tools and the means of evaluating them. We also explored the limitations of the tools of problem solving, the tools of knowledge systems and finally some of the systems tools. When we explored these tools, that are generally resorted to for operating on the functional domain of change and sustainability, we concluded that these were inadequate to operate on the domain of change and sustainability. We also concluded that the continued use of these tools would not get us any closer to operating on change or sustainability.

It was also recognised in the process that the functional domain of change and sustainability is concerned with a *functional unit* and not the *entire* "reality". The tools for systems make the first important contribution in recognising the importance of functional units. However for reasons elaborated earlier, we found the tools for systems inadequate to address the domain of change and sustainability.

The general deficiency in the tools for systems has been that they do not provide an edge to recognising systems; the system lies in the mind of the observer. The logic of systems is therefore elusive, inconsistent and inadequate. Syslogic is a tool which was developed to address the logic of systems. Naturally it originates from criticism of the structural domain of tools for systems[174] and modification of the structural domains to address the criticism.

Syslogic constitutes the first part of the *Toolbox for Tomorrow*. The tools to design tools described in chapter one form the basis for describing and presenting the tools in the toolbox. A concise statement of Syslogic can be found in Appendix 3. Syslogic is compared with the second tool in the toolbox: the general theory of organisation of systems at the end of the next chapter, where the theory is described.

Structural Domain

Syslogic identifies all systems as comprising of actor(s)[175]. Examples of actors who make up a system include: the brain, the heart, the liver, the kidneys, the limbs, the peripheral nervous system,

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[174] Notably System Dynamics whose structural and functional domains are stated in an axiomatic form in Appendix 2.

[175] An actor is anything that acts. Thus the thermostat which acts in response to the room temperature is as much an actor as a human. Throughout this treatise the word actor should be stripped of any "living" organism or human connotations. Shakespeare is not far off when he describes "all the world is but a stage" although he may not have meant it so literally (?) for everything.

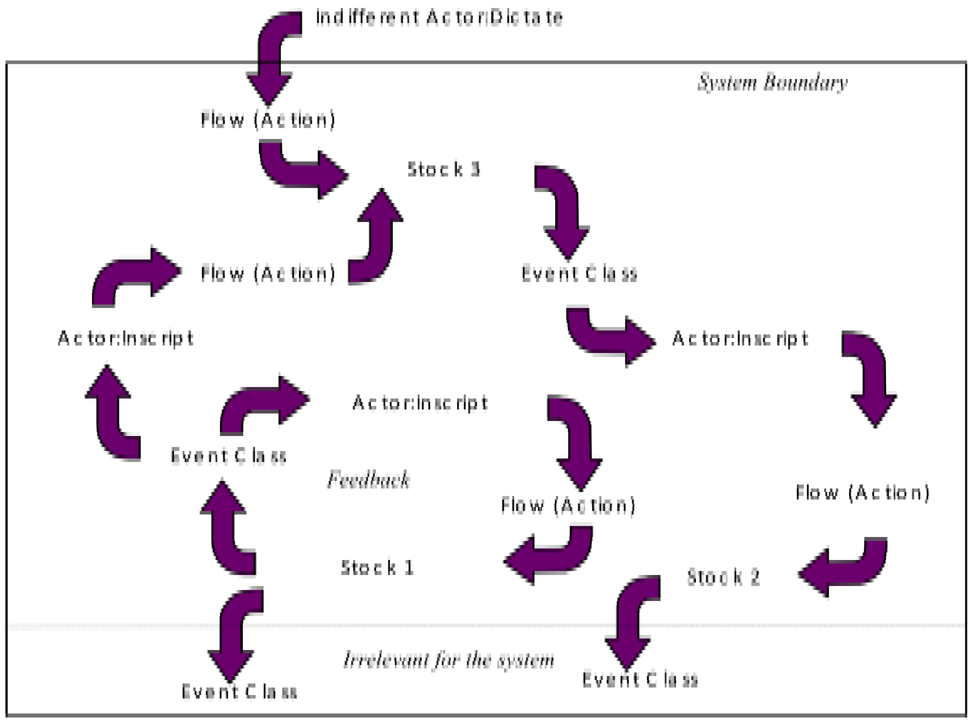

Figure 9 *Overview of the structural domain of Syslogic in a system with an indifferent and an concerned actor illustrating the possible roles the concerned actor can play in the system.*

the lungs which make up the *human body*; The buyers and sellers who make up a *market system*; The lenders and borrowers who make up a *banking system* and the hydrogen and oxygen atoms which make up the *water molecule*.

Actors engage in a relationship which bounds the system. A relationship is a consequence of the action of the actors. For example: the brain stores information sent to it by the peripheral nervous system and processes it. The heart circulates vital nutrients to the body. The liver processes certain nutrients and toxins sent by the heart. the kidney disposes unwanted substances the heart circulates, the limbs move the body as signalled by the nervous system. The lungs exchange air for material circulated by the heart. These are some of the relationships between the interacting actors of the human body.

The actions of transfer of a resource from a seller to a buyer in exchange for another resource constitutes the central relationship in the market system. The transfer of money from the lender to the borrower and the transfers of small amounts of money from the borrower to the lender at periodic intervals constitutes the central relationship in a banking system. Similarly the action of the exchange of electrons between the Hydrogen and Oxygen atoms constitutes the relationship that bounds and defines the water molecule.

***Box 2** Summary of the propositions in the structural domain of Syslogic.*

Definitions:

Stocks are accumulations of something. Stocks can be of kind (books, arms, people, etc.) or of the mind (frustration, love, anger, etc.). A relationship involves the partitioning of some stocks.

Events are happenings. A redistribution of a stock generates events.

Axioms:

A system has a group of Actors.

Actors in a system engage in a relationship.

Laws:

Law of Action: *Actors use inscripts to respond to events.*

Law of Vectoral Action: *Inscripts of actors have a direction and strength.*

Law of Instructs: *Each act is carried out through an instruct based upon a inscript.*

Law of the Act: *An act redistributes a stock.*

The laws of systems dictate the nature of action. The law of action specifies that actors use inscripts[176] to respond to events[177]. For example the brain responds to information from the peripheral nervous system in fixed patterns. The heart responds to "signals" from the organs in fixed patterns altering the rate of pumping the blood. Each actor (organ) reacts to specific events in fixed patterns.

In a market system, the seller reacts to events of shortages or surpluses of resources being exchanged. The seller also reacts to other events using inscripts. The buyer reacts to the same or other events using inscripts that follow a pattern. In a banking system, the lender responds to the several events like the flow of money to or from the borrower. The borrower responds to similar flows with inscripts. The hydrogen and oxygen atoms also respond to events using inscripts.

From these examples it is clear that even if the repertoire of events that trigger action is large or small, inscripts are the necessary means to respond. This is *not* to imply that inscripts are static. The inscripts may themselves undergo change in a system. Such processes are systems themselves that are dependent on the nature of the relationship with a "script writer" who may be a *self aware* actor itself or another actor. Thus it is not necessary to enter the system that creates inscript dynamics in

[176] An inscript is a set of instructs responding to an *class of events*. Inscripts are formulated as rules. An actor lacks an inscript to an event if the actor has no instructs to respond to the event. An actor lacks an inscript to an event *class* if the actor has no rules to respond to that class of events.

[177] An event is a happening that falls out of the "normal" pattern of the observer. An event is thus something relative to the observer. Events evoke a response of some kind. Thus while sun rising is an "event" to somebody watching the darkness of the night, it is not an "event" to somebody who is in a windowless room when the sun rises. An event is necessarily a "process" that lasts over a duration. It can be recognised only when it lasts at least as long as the duration that the observer samples for its occurrence.

order to define a system. Often it may be the case that we lack information about the process of inscript regulation and describe it as a “probabilistic” process.

The law of vectoral[178] action specifies that the inscripts of actors have a direction and strength. The purpose is implicit in the formulation of an inscript. Inscripts never say “just act”[179]; they always specify how to act. They therefore have an underlying purpose. For example the seller responds to shortages or surpluses because the seller wishes to keep a desired inventory or set a exchange rate for the resource being sold. The Hydrogen or Oxygen respond to overfilled or unfilled outer shells to fill them according to inscripts (that may or may not be known to an observer).

The law of instructs dictates that each act is carried out through an instruct[180] based on a inscript. For example the heart “decides” to pump more blood in response to some event. The seller decides to sell at an agreeable price. The lender decides to lend under agreeable conditions. Similarly the Hydrogen and Oxygen “decide” to share electrons under agreeable conditions.

The law of the act dictates that an act redistributes a stock[181]. The heart distributes the blood. The seller and buyer redistribute some resource. The lender and borrower redistribute money. The Hydrogen and Oxygen redistribute electrons. Thus each act redistributes a stock from one pile to another, a source to a pile or a pile to a sink.

As was pointed out in chapter one, the structural domain of each tool comprises of propositions which are assumed true. These structural propositions can then be used to map on to a set of conclusions (or the functional domain). It must be reiterated therefore that the value of such mappings rests on the truth value of the propositions in the structural domain. The functional domain presented next, therefore, apply to a world where the propositions presented above (See Box 2 on p. 43 or Figure 9) can be acceptable.

Functional Domain

It is useful to distinguish actors with a concern to the system and actors who are indifferent. The *indifferent* actors, unlike the concerned actors, influence a relationship but are not directly involved in the relationship. Indifferent actors do not respond to events generated by the state of a relationship in the system. They influence a relationship through dictates which bound the relationship[182]. They can therefore be said to influence a relationship with indifference. As indifferent actors influence the system with an indifference, they lack a feedback. It follows that an concerned actor has at least

[178] A vector has a direction and strength. In a system of human actors one would call vectoral action as purposeful action.

[179] This is if we were to ignore the possibility that even just acting can be to a purpose. For example as illustrated by Shakespeare “though this be madness, yet there is a method in it” (Hamlet: II:II).

[180] An instruct is the actors act of responding to an event.

[181] Stocks are accumulations of things. Anything that can accumulate can be a stock. From books, arms, people to frustration, love and anger there are millions of stocks in the world.

[182] These dictates are not a consequence of what they “observe” is happening in the system. They are usually events which take place in another system, where these external actors are the internal actors. For example the educational institution, which may be the external actor to the classroom, may itself be influenced by other external actors like the education secretary or the education minister, unions and peoples bodies of various sorts.

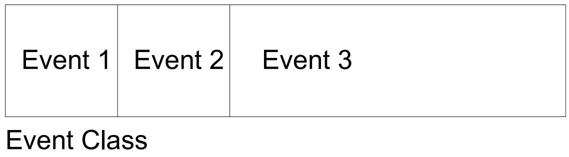

Figure 10 *Relationship between events and event classes. Each event class can comprise of a different set of events depending on the actor experiencing the event class.*

one feedback. It also follows that concerned actors respond to at least some events they attempt to change.

For example the supplier of goods to the seller, the supplier of money to the buyer are among the indifferent actors who may influence the market system. The Lenders association, the finance ministries and the supplier of income to the borrower will be among the indifferent actors in the banking system. They are indifferent so long as they do not (or can not) respond to events generated by the relationship but do influence the relationship.

As all actors can recognise events within *their* event class[183] alone (See Figure 10), realities are necessarily relative. Experience of reality can therefore be shared if two actors can recognise the same events within the same event classes or if events can be mapped to a shared event class[184]. In any system it is necessary for an actor to be able to respond to those events classes which affect the desired event profile. In the "worst" case this is all the event classes in the system, in the "best" case

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[183] An event class is a set of events that are transformations of the same stock. Thus food surplus and food shortfall belong to the same class of events as they concern themselves with food stock.

[184] Quantification attempts to do precisely this. Caws point out that "The variables of physics cannot be regarded as the class of numbers but must be described as classes of pairs, such that for each pair one member is an element of a class of physical entities and the other member is a number. Thus a subclass of numbers is selected from the whole class of numbers by physical selection." (Caws, P., "Definition and Measurement in Physics" in Churchman, C. W., and P. Ratosh, eds., *Measurement: Definitions and Theories*, John Wiley and Sons, New York, 1959, p. 11). He further points out that "in some world other than ours, there are intelligent beings who have not discovered mathematics but whose organs are so constructed as to give them enormously heightened sensitivity to colour, so that they can distinguish many distinct shades within what to us is a narrow spectral band. Suppose they have discovered fire and the metallurgical arts. Their fundamental metric then might be the colour scale of temperature. This provides unambiguous relations of coincidence and precedence; our phrase "greater than" would be rendered "bluer than" and there would be other changes of a similar kind. A calculus of colours could be worked out, for the combination of two particular colours determines a unique third, and a standard colour might be selected the combination of which with any other would be an operation analogous to "+1" in arithmetic. The colour system would not be simply linear, of course, but that might be an added advantage..... Temperature would be a "fundamental quantity; length could be defined in terms of it via a thermometer readings, time by means of some periodic phenomenon such as the passage of heat waves through a long metal rod, work (and derivativly, force, mass, etc.) via the Carnot cycle, electric properties via the thermocouple phenomena. The inhabitants of this world would have quite clear ideas of these other things on their own grounds, but somebody would probably tell them sooner or later, that their concepts had no meaning apart from a technique of assigning to each occurrence of them one and exactly one colour, i.e., defining them operationally" (p. 11-12).

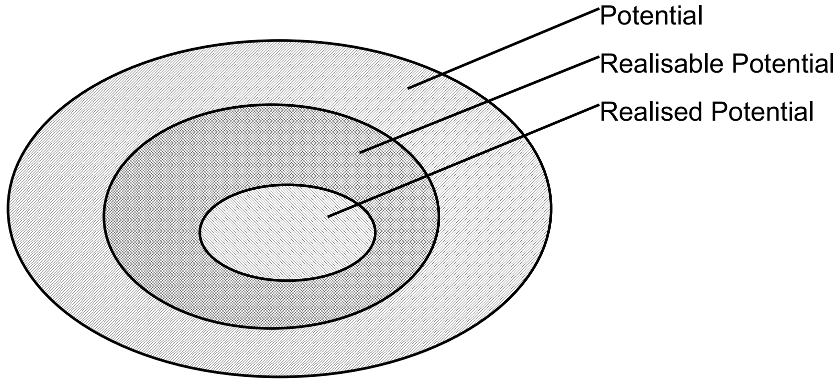

Figure 11 *Potential, realisable potential and realised potential in relation to each other.*

it is a subset of the subset of event classes that generate the desired events. This is crucial as it points out the possibility of not needing to respond to every event class in the system in order to keep a desired event profile. It also points out that even as the desired event profile covers all the event classes, all event classes need not necessarily be responded to.

The behavioural profiles of a system can be described in terms of the events that occur in the system (See Figure 11). The actual set of events that take place in the system describe the potential of the system realised as a consequence of a particular set of decisions on part of the actors during the course of time. The realisable potential of a system is the set of event profiles that are realisable in practice through different decision possibilities for the actors. The realisable potential is bounded by the dictate of the indifferent actors. The potential of a system is the set of event profiles that can be potentially generated by the relationships that make up the system. The potential is bounded by the nature of the relationship alone.

The most crucial question about a system is about its potential. As the potential is what is defined by the relationship, it cannot be changed without changing the system. In reality only a subset of the potential is realisable because of the constraints imposed by the indifferent actors. Concerned actors can change their action inscripts in order to alter the realisable potential within the potential. The realised potential, or the systems actual event profile, is what is realised by the specific decision set from a given inscript set for the actors in the system. Two systems of identical actors who differ in their inscripts (*response isoforms*) differ in their realisable potential. Two systems of identical actors with a different relationship (*reactive isoforms*) differ in their potential of a system.

The Implementation

Descriptions of systems using Syslogic can be made in the Language NOW (See Appendix 4 for a description of the language NOW). The language NOW has been designed to keep compatibility with languages that allowed to represent System Dynamics models[185]. This was largely to facilitate System Dynamists a possibility to convert their existing models, with rich insights, for operating on

[185]For example Dynamo™ from Pugh Roberts and company and Stella™ from Hi-Performance Systems.

wider domains. A software programme[186] has been implemented to include an interpreter for NOW. Models of systems written in NOW can be "loaded" into the visible toolbox. The visible toolbox then interprets the description and allows the user to explore the system which has been modelled.

Explorations into the system can be to understand the system (from a researchers perspective), to communicate the system (from an educators perspective) or to manage the system (from the managers perspective). The visible toolbox allows the user any perspective and adapts the exploration to suit the needs of the perspective. The interface of the visible toolbox is described in detail in Appendix 5.

Using Syslogic

Syslogic is simple and intuitive to use. The typical use of Syslogic is for analysing systems. If the intention is to operate on a system for *basic* understanding, communication and *basic* management building a simple pictorial model of the system using Syslogic suffices. For detailed understanding or for extensive management, pictorial models need to be transformed into computer models in a language similar to NOW.

Pictorial Models

Given a system under observation, the first step is to identify the acting actors in the system. Actors, as pointed out earlier, are anything that acts. Keeping the anthropocentric viewpoint on actors away one can list actors by simply collecting the actions in the system and identifying the responsible actor. If actions (and hence relationships) have not been automatically elucidated in the first step, then they need to be identified in the second step. Actions are lists of event-decision pairs that occur in the system. They are easily identified by looking for events important to or responded to by actors. Alternately when decisions of actors can be identified, their actions can be identified.

In the next step action lists are sorted to collect all events of the same event class together in order to construct the inscript of the actor. Actors without an inscript are definitely indifferent actors. Pictorial maps of the kind in Figure 9 on p. 42 can now be constructed to give a good idea of: the purpose of the system, the concerned and indifferent actors, the system boundary, the actions of concerned actors, the dictates of the indifferent actors and the events (and event classes) that need are important to the actors within the system.

Computer Models and Simulation

In order to transform the pictorial models in to a computer model, the easiest and quickest route is to convert the pictorial representation into NOW. Alternately the pictorial model can be converted into any standard computer programming language like Basic, FORTRAN, Pascal, C, C++ or even simulated on a spreadsheet that supports object linking and embedding (OLE) under Microsoft Windows with some ingenuity.

Using Standard Computer Languages

There are many ways in which the pictorial model can be implemented in standard computer languages. The ease depends on the possibility offered by the language to represent the objects of Syslogic in appropriate data structures for simulation. Generally object oriented frameworks will offer ease for these operations and provide extensible feature packed and maintainable simulation

[186]The software programme is referred to as the Visible Toolbox.

models. Other computer languages are likely to provide a other “data structures” to model new situations each time.

As with several simulations systems of systems with accumulations, methods of integration are used in order to simulate time steps. The most popular integrative system is that of Euler. Despite the fact that Euler’s method generates errors of integration, its ease of implementation and speed of execution make this the widely preferred method to simulate time step accumulation. The general procedure for this method requires initial values for accumulators. Based on these initial values the initial flows are computed. The virtual time clock is set to initial value and the procedure of computing stocks and flows alternates for every virtual time step (when the virtual time updates by the time step) till the virtual end time is reached. The accuracy of this method to synchronise the events with virtual time decreases as the virtual step time increases (See Figure 12 on p. 49 for comparison of the loss of synchronisation as the time step increases). A virtual step time equal to half or less than half of the shortest time interval of interest in the system is used to keep the events synchronised.

Alternative methods like the Runge-Kutta methods of different orders can also be explored to simulate time steps. Higher virtual times steps can still keep the events synchronised with the virtual time in case of this method. The basic difference between Euler’s method and Runge-Kutta is that the flow calculations for *every* iteration are based on averages of flows projected into future time points. For example an 2nd order Runge-Kutta the stock calculations are:

$$\text{Flow } 1 = \text{dt} * \text{Function}(\text{time t}, \text{stock x}) \quad \text{(a)}$$

$$\text{Flow } 2 = \text{dt} * \text{function}(\text{time t} + \text{dt}, \text{stock x} + \text{Flow } 1) \quad \text{(b)}$$

$$\text{Final Flow} = 1/2 * (\text{Flow } 1 + \text{Flow } 2) \quad \text{(c)}$$

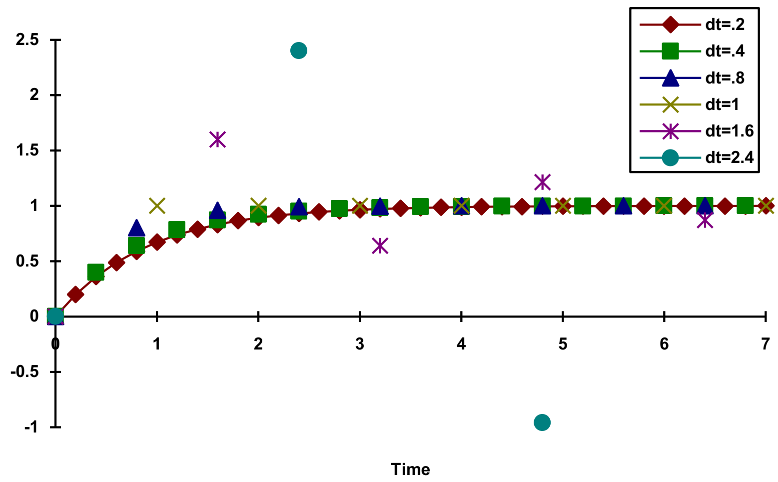

Figure 12 *Errors generated by Euler's method of integration as the virtual time step increases for the equation: At virtual time step=.2, the solution is close to the analytic solution. As the virtual time step grows through 1.6 the stock begins to oscillate around the final value but eventually converges. When the virtual step time is 2.4 or larger, the stock oscillates and diverges more and more from the analytic solution. Thus while eventually they can yield correct values, the stocks do not remain synchronised with the virtual time point.*

$$Stock9stock(now0 = \int_{Start\ time}^{End\ time} stock(before) + \left(1 - stock(before)\right) * dt$$

Using NOW for Simulation

The first step in the conversion of the pictorial representation into NOW is writing a stock statement for each event class (See Appendix 4 for the detailed syntax of each of the statements referred to here). The flows in the stock statement are identified by the action statements that affect the event class. Each flow statement is written to specify the inscript and each inscript in turn is written to identify the actor. Use of intermediate computation variables is made only where the limitations of NOW dictate as necessary. The events of each inscript are described in event statements. A Run specs statement is added to specify the virtual time frame for simulation and the virtual time steps for computation. The computer model is now ready for syntax checking before any simulation.

Currently using NOW in combination with the *Visible Toolbox* is the ideal option as the *Visible Toolbox* can interpret and simulate the statements in NOW. The *Visible Toolbox* (Described in Appendix 5) uses the Euler method for simulation and therefore the user must choose appropriate virtual time steps. The *Visible Toolbox* can and does make use of every bit of information packed into the NOW statements. The users operation specific interaction is guided through a filtered relevant set of propositions about the system. Thus the user can explore the system for understanding, communication or managing without information burdening while yet getting every relevant bit that is known about the system.

Evaluation of Syslogic

Syslogic like other tools, is subject to evaluation. Objective evaluation of tools is possible using the tools for evaluation of tools specified in the earlier chapters. As a first step it is important to explore whether Syslogic has the same "deficiencies", when operating on the domain of change and sustainability, as tools of problem solving, knowledge systems and the tools of systems were pointed out to have. Syslogic does not contain problem defining propositions in its structural domain. Syslogic does not seek solutions to any problem. It therefore can not lead us to a problem solution spiral, for whatever else it may do.

Syslogic provides its users with the ability to map systems of their interest directly from reality through the identification of systems. No intervening maps are necessary as the starting point is the actors and their actions. It therefore does not encourage amplification of maps of reality, thus preserving relevance of the propositions that are mapped. Syslogic does not provide a moving definition of systems; It resolves this issue by definition. Actors are the constant feature of a system. It is therefore the first step towards overcoming the "deficiencies" of the earlier systems tools.

Owing to the ability to define a system with greater precision then its predecessor tools, it is in a better position to identify the system as the unit to be sustained. As the events of importance to the system and the actors within can be explored in Syslogic, there is a possibility to operate on the domain of change as the actors in the system perceive it. Syslogic therefore qualifies as a tool that can operate on the functional domain of change and sustainability.

These positive features do not to imply that Syslogic is free of any deficiency and cannot be criticised. The structural domain of Syslogic can be criticised on several grounds. The first criticism against Syslogic is undoubtedly the *à posteriori* argument about actors constituting a system and engaging in a relationship. While the observations on all known systems seems to indicate the "truth" of this statement, it is not satisfactory to base a tool on any *à posteriori* statements as these propositions are secondary propositions and not primary. It therefore not only restricts the scope of the tool but also provides for potential objections and exceptions in the future.

Like its predecessor tools, especially System Dynamics, Syslogic uses the artificial concept of stocks in its structural domain. The relevance of such a secondary proposition can come to be questioned as can its restriction of the scope of the tool.

It is obvious then that while Syslogic offers a good working tool, Syslogic is far from a having attained complete adequacy for the desired tasks. This is precisely why the need was felt for a more general tool that can address the functional domain of reality. It was also felt that the tools of modifying the structural domain would not suffice to generate such a tool, but rather it was necessary to resort to a search for a structural domain that can map on to the functional domain. The tool and the process are described in the next chapter.

Chapter 4

General Theory of Organisation of Systems

Origins

Since change and sustainability have to do with an order or organisation, it can be asked if indeed there exist any tools that operate on the continuum of organisation from matter particles to social systems and change. One can immediately ask the question if indeed there is organisation across this continuum; for if no organisation exists, the question of a tool becomes irrelevant. If indeed organisation is a universal phenomena, then in fact one may first ask if indeed *universal* tools operating across the continuum can exist. If indeed there is the possibility of such tools, it is natural to ask if such tools can also address the domain of change. It becomes interesting then to ask what the nature of such a tool can be.

Every discipline from biology, physics, chemistry to economics and sociology searches for laws that explain the regularities of the subject of observation. It follows that the scientists in these disciplines in their collection of empirical observations and "discovery" of laws, implicitly display or expect organisation or order. If such demonstration or expectation were unreasonable, no science could exist. It is therefore reasonable to conclude that organisation is universal.

Now let us turn to examine the question of the *possibility* of a tool operating on this continuum of organisation from matter particles to social structures. Any tools which can indeed operate on this continuum, will need to build *some* proposition in its structural domain that is universal, or holds true, across this continuum. At least three propositions can be said to have such universality; whatever exists exists, things can not exist and not exist at the same time and everything must exist or not exist[187]. Sometimes a fourth proposition which is also considered to be as universal is that "nothing happens without a reason why it should be rather than otherwise"[188]. The existence of such universal propositions indicates that tools that operate over the continuum *can* indeed be designed. In fact the tool of logic (or reason) which applies these propositions in its structural domain does in fact apply across this continuum[189].

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[187]These propositions have been referred to as the "laws of thought" upon which the mathematical theories of logic and probabilities were based by Boole (See Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, p. 39-51 where Boole derives these propositions as the laws of thought). These propositions are also called the law of identity, the law of contradiction and the law of the excluded middle.

[188]See for example Jevons, S. W., *Elementary lessons in logic: deductive and inductive*, Macmillan and Co., London, 1928, p. 125.

[189]One could therefore call logic or reason the theory or tool of existentialism.

The fourth "universal" proposition above can be argued to justify "reason" in change. It is however clear that it provides no clues to the nature of change or the cause of change. It can be argued that this fourth proposition is not "primary" as the other three, as it can follow from some primary propositions, if they can be found, that are universal in explaining change. Thus it can be said that this tool does not address the domain of change adequately.

From the foregoing, we are then in a position to conclude that there can indeed be a possibility of constructing tools that operate across the continuum of organisation from matter particles to social systems and that can possibly operate on the domain of change too.

The design of such a tool is precisely responsible for the theory of organisation of systems. Unlike Syslogic, whose starting point was in the tools of systems, which rest on *à posteriori* propositions or "analysis", the starting point of the theory is not on any analysis. The theory of organisation of systems has been derived from a "search" for the "simplest possible system of thought that will bind together observed facts"[190] about the nature of organisation of the universe in a manner similar to that described in chapter 1. The theory of organisation of systems is presented here in a format similar to the one in which Syslogic was presented for identical reasons. A concise statement of the structural and functional domains of the theory can be found in Appendix 6.

Structural Domain

From the universal propositions described above, it is apparent that *there is*. This simply means that existence of something is beyond dispute or universal. Importantly this is irrespective of any resort to metaphysics. The starting point of such a proposition is not in observing what is, but simply through mental constructs.

It is also universally axiomatic that all acts are necessarily in response to some event. This is obvious as acts will have no meaning if they were not to be a consequence of something[191]. An observer looking at the acts of anything actually perceives the acts of anything as events themselves. For those who base their thoughts primarily on observation it is important to point out that the observer may or may not be able to note the event which the thing responded to through the act. This is obvious especially after our discourse in Syslogic in the previous chapter.

By virtue of the above axioms, all existents are actors. This can be regarded as the *law of the nature of identity*. It also follows that actors act. An actor who cannot act is impossible by definition. This is therefore the *law of role*.

In every act an actor necessarily modifies some attribute of an actor. An act has to be on some existent and all existents are actors. This is also the *law of characterisation*. Existents can not be created or destroyed. They can only be transformed. This *law of conservation* follows from the axiom that *there is*. For something that is cannot become not is, it can only be transformed to something else.

Being the simplest possible mutually independent propositions the laws are the fundamental basis of the theory of organisation of systems. These propositions can be verified empirically, however

[190]Einstein, A., *Essays in Science*, Philosophical Library, New York, 1934, p. 113.

[191]As pointed out in the previous chapter purposeless acts are impossible. This implies that they have to be triggered by something that the actor monitors. To quote Shakespeare, who put it well, "though this be madness, yet there is a method in it" (Hamlet: II:II).

their derivation has nothing to do with observation and analysis. The law of the nature of identity, the law of role and the law of characterisation find empirical validation in the observation of every scientist through the "discovery" of the laws that "explain the behaviour" of their subject of study. The law of conservation finds empirical validation in the much quoted examples of the "laws" of conservation of matter (Lavoisier[192] 1789) and conservation of energy (Mayer[193] 1842) which can be seen as a special case of the conservation principle.

Functional Domain

It is useful to review and refine our idea of event in light of these structural propositions. While an event[194] is indeed an happening in the eyes of an observer, it is necessarily *an actor with a particular characteristic*. Acts are also events for an observer; an act necessarily creates an event as it modifies a characteristic of some actor. Within a system, it makes little sense to treat an act as an event unless some actor responds to the act, rather than the event generated by the act.

We can coin the term *reactivity* for the ability of an actor to *recognise* and *respond* to an event. Thus an actor who cannot recognise to an event lacks reactivity to the event. So does an actor who can recognise but not respond an event. We can coin the term *role* for the actors ability to *recognise and participate* in the system. An actor who can recognise a system but not participate is an *observer*. An actor cannot participate unless the actor can recognise the system.

Given the structural domain described above it is possible to map out as a functional domain a world based on such a structural set of propositions.

From the structural propositions, it becomes apparent that a world without actors is impossible. If something does exist and all existents are actors then actors need to exist. Alternately if we imagine a world devoid of all actors, all change in this world will need to be attributed to a "change demon" which can note every state and respond to it. By doing so the demon would then be an actor itself. Thus an actorless world is impossible.

As an important corollary to this proposition we can add that no organisation is possible without an actor. Any organisation is a part of the world. If the world cannot be actor less, an organisation cannot be actor less.

Another important corollary is that the simplest unit of organisation is an actor. Organisation cannot be reduced to simpler units than an actor. This follows from the necessity for organisation to have actors. It is also evident that actors exist irrespective of the metaphysics resorted to by the observer.

When actors act they modify some attribute of another actor by virtue of the law of characterisation. It follows that from a pool of actors acted upon, the actor moves another actor in to some partition characterised by the attribute acted on. Actors thus redistribute the actor they act on in partitions on the basis of some characteristic that causes the act. For example the by preying, the predator redistributes the prey between the eaten and uneaten.

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[192]Trattner, E., *Architects of Ideas: The story of the worlds great thinkers*, The New Home Library, New York, 1942, p. 116-117

[193]*ibid.*, p. 139.

[194]It is important to note that the concept of event has now been generalised even further to eliminate the need for observation frame.

It becomes apparent from the structural domain that reactivity defines what an actor can respond to. If an actor has no reactivity (recognition or response abilities) to an event, then that actor cannot respond to it. While this can be viewed as an domain restricted, this proposition also communicates the role of reactivity as a domain definer. If an actor has reactivity to an event then the actor will react to it.

So far the idea of system has eluded the theory. How does a system come to be? When actors with reactivities to a common actor encounter each other, they *organise* around a relationship to constitute a system. For example the atoms who have reactivity to each other can organise around a relationship to share electrons constituting the system of a molecule. Similarly a buyer and a seller having reactivity to a resource on exchange, organise around a relationship to constitute a market system.

If the reactivities of actors *define* a system, then the system associates (or expands) with other actors or systems to accommodate the combined reactivities of its actors. It is important to recognise that the reorganisation results in a *new* system. For example the buyer and seller also have reactivities to loans of a resource. They can thus associate with a lender of resource to constitute a larger market-bank system. Similarly certain bacteria have a reactivity to Nitrates and normally engage in a relationship with the nitrates to constitute an atmospheric fixation. However on encounter with leguminous plants, these bacteria engage in a relationship with them to exchange nutrients constituting a symbiotic nitrogen fixing system. It is then clear that new reactivity or new encounters is what makes reorganisation into new systems possible.

Just as association expands systems, disassociation contracts systems. When one or more actors can not service one or more of their reactivities, systems disassociate or contract. Under high thermal conditions molecules break up to simple atoms as the individual atoms can not service their reactivities to each other. When the buyer and the seller are physically separated, they cannot service their reactivities. The market system thus disassociates. Similarly under constraints of resources on exchange, the buyers or the sellers may not be able to service their reactivities. The system thus disassociates.

As it is the inscripts which govern action, for reasons identical to those discussed in the previous chapter, it is these inscripts which decide the *rate* of partitioning of the actors in the system. Thus it is the inscript on purchasing a good that decides the rate of partitioning of buyer with or without the good. Similarly it is the inscript of sharing electrons that decides the *rate* of partitioning of free atoms and molecules.

A system is closed to reorganisation if every actor in the system has at least one actor with reactivity to every characteristic distinguishing the actor. No example of a system that is permanently closed to reorganisation can be imagined. The water molecule is closed to reorganisation as hydrogen and oxygen atoms have reactivity to every characteristic defining their relationship. So are many “stable” molecules. If the atoms could form relationship in isolation then they would indeed constitute systems incapable of reorganisation. However such isolation can only be forced for sometime. As an important corollary it is possible to state that a system is open to reorganisation if no actor within the system has reactivity to any characteristic of at least one actor. The molecules in the example above are thus open to reorganisation because they do not have reactivity to at least one other actor: heat.

It is important to recognise that systems that reorganise usually have actors who have a feedback[195] of their action. Such feedback is possible if for the event in response to which an actor modified a characteristic of another actor, there exists some actor who can sense the original or modified characteristic, and who, through similar recursion or directly, can modify the event. It is clear that all theories of feedback dynamics (Such as Forrester's theory stated in Appendix 2) apply to describe the dynamics of these actions.

A very important conclusion we can draw from the structural domain is that a system is sustained *only* if the relationships within can be sustained. Thus for example if the atoms in molecules can no longer share electrons, the molecules can not be sustained as molecules. If the lender and the borrower can no longer exchange resources, the banking system cannot be sustained.

Observers of systems observe the system and its behaviour only through their own reactivities. It follows that they can observe events that the actors within the system do not have a reactivity to (and are therefore irrelevant to the system). A trivial example of this is to imagine a scientist concerned with growth but unfamiliar with chess watching the game of chess. The scientist would not wrongly conclude that the chess pieces on the board decrease exponentially. Those familiar with chess know that the exponential decrease of pieces on the board is hardly the observation or concern of the participants in a chess game.

Using the Theory

The general theory of systems is almost common sensible in its statement. Like logic or reason, whose primary propositions seem absurdly common sensible, this theory offers the same simplicity[196]. The theory can be used to understand, communicate and manage systems. It provides a dynamic or ever changing world view of existents. It thus it offers the possibility of supplementing the traditional tools of reasoning or logic to draw conclusions about a *dynamic* world.

The tool provides the simple *building blocks* of systems it also provides a framework for *designing* systems. The theory being independent of the *physical* nature of systems provides the possibility to design systems with diverse physical forms that exhibit similar behaviour.

The theory can also be used to analyse systems. Once the reactivities of the actors of interest are identified, their abilities to form systems can be examined. Consequently the properties of these complexes in terms of the full life cycle can be explored by applying the theorems. Depending on the needs, this process can be done manually or tools similar to the *Visible Toolbox* can be implemented to make the process simpler and faster.

For the use of the theory, for both analytic as well as synthetic ends, it is possible to use the theorems to explore resultant organisations on combinations of elements. The properties of such organisations

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[195]Feedback is *not* awareness. A thermostat has *feedback* through recognition of the room temperature. This does not imply it knows that it can recognise its actions. *Awareness is the reactivity to ones own reactivities and inscripts*.

[196]It can be argued that if (traditional) logic is a(n) (collection of) inference method(s) for drawing inferences about existents that are unchanging, the theory of organisation of systems provides inference methods that can draw inferences about existents which have *life cycles* and exhibit different characteristics in the presence of other existents.

can then be explored and compared. A more detailed statement on the use and consequences of the theory can be found in part three of this treatise.

Evaluation of the Theory

The theory of organisation of systems satisfies the following criteria: it does not use problem solving propositions in its structural domain. It therefore can not lead to a problem solution spiral. The theory also maps the real world *directly*. The propositions of existence and the nature of existence are the simplest propositions one could use to map reality. The tool therefore does not amplify the propositions of the real world but provides a strong attenuater built in. All propositions need to map onto the collection of existents (actors) and their reactivities alone. The full spectrum of real world observations can be derived as secondary propositions using the tool as and when required. This tool also provides an *universal* criteria to identify systems, however transient the systems may be. Giving us the *reactivity* to systems the tool allows us to generate new *inscripts* to respond to systems. It provides, perhaps for the first time, a building block for all organisation, *irrespective* of the physical nature of the organising substance. This is simply because no characteristic of existents is assumed other than declaring them to be actors.

The theory certainly can not be criticised for being based on any *à posteriori* statements. While the "laws" in the theory are secondary propositions they follow from the axioms of the theory. They thus do not restrict the scope of the theory. The tool thus seems to be the most adequate tool thus far in operating on the domains of change, sustainability and organisation.

The tool in providing for the laws of organisation allow to operate on change in systems through reorganisation as well as change within a system. Thus it explicitly operates on the domain of change and sustainability.

This is not to imply that the mapping of the tool has been evaluated completely. The functional domain of the tool remains to be completely mapped. The consistency and validity of the propositions in the functional domain mapped on to needs to be explored too. These are minor shortcomings in the evaluation as can be recognised now.

Comparison of the Tools in the Toolbox

The overlap of terminology and the ability of this theory to encompass Syslogic and theories of feedback dynamics can raise the question of the need for independent tools or the difference between Syslogic and this theory. Both tools have been described under similar headings to make comparison possible and easy. The salient differences are summed up in Tables 2 and 3. From the criteria to compare tools, laid down in chapter one, the strengths and weaknesses of the tools can become apparent on some contemplation.

Table 2 *Comparison of the structural domains of Syslogic and Theory of Organisation of Systems*

	Syslogic	***Theory of Organisation of Systems***
Definitions	**Stocks** are accumulations of something. Stocks can be of kind (books, arms, people, etc.) or of the mind (frustration, love, anger, etc.). A relationship involves the partitioning of some stocks. **Events** are happenings. A redistribution of a stock generates events.	No definitions in the *structural* domain.
Axioms	*A system has a group of Actors.* *Actors in a system engage in a relationship.*	*There is.* *Acts are a response to some event.*
Laws	**Law of Action:** *Actors use inscripts to respond to events.* **Law of Vectoral Action:** *Inscripts of actors have a direction and strength .* **Law of Instructs:** *Each act is carried out through an instruct based upon a inscript.* **Law of the Act:** *An act redistributes a stock.*	**The law of nature of identity:** *All existents are actors.* **The law of role:** *Actors act.* **The law of characterisation:** *All acts modify some attribute of some actor.* **The law of conservation:** *Existents can not be created or destroyed, only acted on.*

It becomes immediately apparent that the structural domains of the two tools are different. The propositions in the structural domain of Syslogic are *à posteriori* in contrast to those in the theory of organisation of systems. The axioms of Syslogic are mutually dependent unlike those from the theory of organisation of systems. While the functional domain of the first tool is restricted to systems whose actors are *observed*, the second tool applies across all universes irrespective of whether observation has been made or not. The latter therefore encompasses the former.

In presenting building blocks for all systems irrespective of their *physical* characteristic the latter also unifies all fields of endeavour and serves as an *unifying* theory. Such an unifying theory is not only able to draw conclusions about the nature of relationships between the components of a system but also about change and sustainability of such systems.

As was pointed out in the sections describing the use of the tools, the first tool can be used analytically to understand, communicate and manage systems. The elements of systems as identified by Syslogic normally need to be "analysed" or observed in the real world for the use of Syslogic. While a synthetic system (or a system which has components *by definition* or *by design*) can be constructed in Syslogic, it can not draw any conclusions on the possibilities for such complexes to

Table 3 *Characteristics of Syslogic and Theory of Organisation of Systems compared.*

Characteristics	***Syslogic***	***Theory of Organisation of Systems***
Mapping	Not Evaluated	Not Evaluated
Structural propositions	*à posteriori*	*à priori*
Mutually independent axioms	No	Yes
Functional domain	System	Universe of reorganising elements
Usage	Normally as an analytic tool	Synthetic and analytic tool
Implementation	As software under MS Windows™	Only as a theory

exist in the real world. The theory of organisation of systems on the other hand can be used both analytically and synthetically. Synthetic complexes of elements not only allow to explore what characteristics will result as a consequence of these *encounters*, but also of the behaviour of these complexes. This provides us with certain advantages which are dealt with in part three of the treatise.

While Syslogic has been implemented to allow semi-automated explorations of systems in the form of a *Visible Toolbox*, the theory of organisation of systems has not *yet* been automated to allow explore the dynamic life cycle of systems organisation.

Eavesdropping

“Yes, all this. But so what?”

“You mean what can you do with it?”

“Yes, yes.”

“Don’t you first need to see and examine every tool before you know or learn what to do with it?”

“That is certainly what we do. But with this .. it seems so odd.”

“I guess that is because we are so used to the claims being mixed with what it is.”

“..And of course the claims follow as a consequence of the structure?”

“Naturally!”

“I can already *see* what one can do with these tools!”

“This Syslogic means we must ignore the theories of biologists when modelling predator prey?”

“I think you are missing the relevance.. When is a proposition relevant to a tool?”

“You mean the whole of biology is irrelevant to predator prey? Tell that to a biologist..”

“I am one, you know. Anyway you draw invalid maps from my premises onto such conclusions.”

“Did you not *see* what we read about relevance? Will you play chess using the proposition that pieces decrease with time?”

“How is that relevant?”

“Well, simple it is relevant as relevance and the tool of establishing relevance have everything in common!”

“Uh-huh.”

“And don’t you see that is precisely what he is talking about.”

“I think it’s beautiful. Look here. We are a group of ‘actors’ reacting to ‘events’ of encountering these strange ideas...”

“... Each of us has different inscripts”

“... You have such an idea killing inscript, and you one to question, and you to be cautious, you prefer ...”

“Yes, yes. But I am self aware. My ‘inscripts’ (if you will) change.”

“Of course they do! If you were self aware you would be doing that now too, would you not...”

“Don’t laugh. This is pretty well serious. That again is the elegance of Syslogic.”

"But you seem to be drawing on unstated conclusions.."

"My dear Watson, conclusions follow from the premises. That is what the tools *for* the toolbox are about. Then the only claims, all verifiable by logic, lie in the conclusions alone!"

"Say, everyone! Look what I found ...."

Systems

A system has a group of actors, engaged in a relationship that matters.
Over the life of the system, each responds to the events within,
With rules so fine designed to win, god forbid they forget and sin!!

Actors

An actor is the constant member of the system yonder.
His acts one must remember, use rules framed by his ancestor.
With purposes in temper that consider the encounter
With the events that matter lets take them with humour.
What then it is let me dare ask, of the encounter which was not of past?
The actor in all his wondrous past, must then seek out a new cast.
Design he must a new relationship or rule, to keep himself and his cool!

Events

Events are happenings that can be sensed, they occur in succession and over a duration.
Some we note with great concern, as they stand out in distinction,
Others we forget with great ease, as those that we do everyday lease!
They form the basis of our experience, to create rules with great perseverance.
It follows then lest we forget, what we do not sense we do forget!

Inscripts

It's inscripts that guide the instructs whether significant or not,
each inscript is to a purpose whether you remember it or not.

Stocks

Stocks are of kind and also of the mind, they always pile or deplete,
But take too long for the act to complete. unless the flows resolve to cheat!
Stocks it is that we sustain, if a balance in its flows we can maintain!

Flows

From a source or to a sink flows it is that move whatever you think.
As long as the inflow will exceed the outflow, the stock they feed shall always grow.
As long as the outflow will exceed the inflow, the stock they feed will never grow.
When you match the outflow with inflow, steady state is what the stock will show.
That's the way that flows decide, how long it will be before the stocks shall rise.
Ancient wisdom when forgotten, shall decay the system or make it rotten.

"The absence of actors and events must be precisely why models have been considered esoteric?"

"I guess so. Look at the *Limits* model[197]. Despite its spectacular success in pointing out that something was wrong, it remained inaccessible in terms of what you and I can do."

"Or in fact the other global models[198]..."

"Yes. They did not have the tools to represent actors and events then..."

"If it could raise concern so much without actors or events, imagine what could have been possible with Syslogic then!"

"Yes but what of this theory? I don't see any difference from Syslogic."

"You haven't developed the reactivity? Well we better go back to the tools he tried to equip us with.."

"Reactivity?"

"..to each tool. Recognising a tool through its structural domain."

"Ah! You mean premises and conclusions that he fancifully (and confusingly) calls structural and functional domains?"

"Yes. The very same. Don't you see the difference?"

"I think it dawns on me gradually. But I still do not see the point of such a laborious excursion with so many fanciful definitions."

"In this theory we don't really assume anything but existence."

".. don't forget the other axiom about acts being a response to some events."

"Like this conversation now.."

"Then a system cannot organise itself if actors do not have reactivity..."

"Precisely."

"Is that not common sense?"

"But so are so many other things.. when they are stated."

"But this is so simplistic.."

"So are bricks that make up the complex buildings we construct.."

"..so are the simple atoms that make up complex organisms.."

"You sound as if the goal of science is to complexify, and therefore everything simple must be wrong.."

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[197]Meadows, D. H., D. L. Meadows and J. Randers, *The Limits to Growth*, Earthscan Publications Ltd, London, 1972.

[198]For a summary of the "first ten" global models see Meadows, D. H., J. Richardson, and G. Bruckmann, *Groping in the Dark*, Wiley and Sons, New York, 1982.

"No, no. I agree we must simplify in science. Just this simplification stands out in everything so complex that I read for the past several years."

"These are indeed building blocks for organisation!"

"Then we can use them for building too..."

"Look at this, everyone.. Here we are with our different reactivities to what we have just discovered.."

"..we organise around this till some other reactivities are in service and then reorganise to a new system!"

"For some of us this may even add to our own repertoire of reactivities! That is if we are self aware and not run by inscripts alone!"

"I can see whole new possibilities of discovering a different place where we are through something like this.."

Part Three

Scope and Applications of the Toolbox

Some potential application areas that follow from the tools and some of the resulting consequences for these areas.

Chapter 5

Understanding and Communication

Syslogic

As the first step in sharing an understanding and communication of systems, it is necessary to agree on what system is being communicated. Syslogic defines systems through the only constant thing in a system: actors. Actors engage in a relationship to constitute a system. As was also pointed out earlier, the potential of a system is defined by the relationships that define the system alone. Syslogic therefore allows focus on the system and estimate the potentials of systems[199], leaving the question inscripts of the actors to respond to events and the dictates of the external actors to the research of scientists studying such systems. The estimates of these scientists on the inscripts and the dictates of the indifferent actors help explore the realisable and realised potentials.

For example a market system is described by a buyer and a seller. A banking system is defined by a borrower and a lender. Within the framework of either system, a whole range of inscripts are possible to define the realisable potential within the constraints set by the external actors.

When a system is defined in terms of actors and the events they respond to, it is possible to segregate the "event experiences" of different actors participating in a system to understand and communicate the relativity of every experience. By specifying the inscripts Syslogic allows explore the influence of each actor and each decision of each actor on the realised potential of a system. Syslogic also allows to illustrate that actors can react to only certain events and therefore inherently can not react to others. It also becomes possible to understand events relevant to the system and irrelevant to the system by observing if any actor within the system actually is affected by or reacts to the event.

Through the ability to differentiate internal and external actors, Syslogic provides the possibility to understand the role of any actor in generating the realised event profile of the system. Syslogic thus makes it possible to understand and communicate a complete picture of any moment in the life of a system.

The general understanding provided by Syslogic is however *à posteriori* as the components of the system are usually observed through the analytic tools of Syslogic. This means that some analyst needs to observe the system, identify the actors and the relationships that constitute the system before it can be communicated.

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[199]It has been pointed out earlier that potentials are defined solely by the relationship that defines the system.

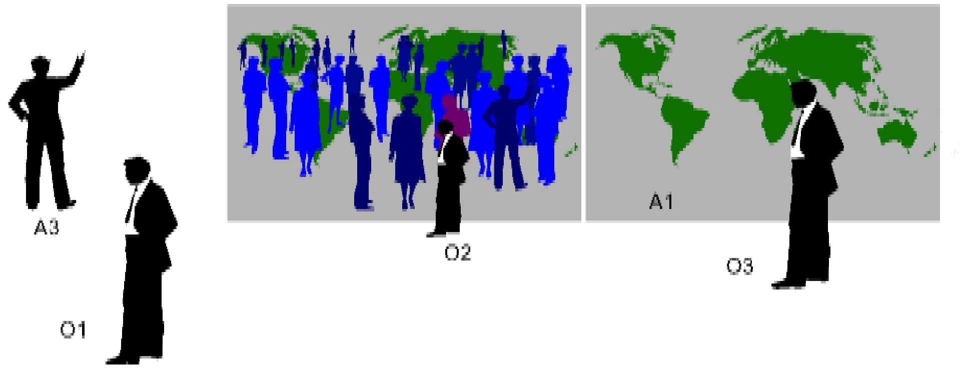

Figure 13 *The observer "observing" a "system".*

General Theory of Organisation of Systems

The general theory of organisation of systems provides the possibility to understand and communicate the organisation of a collection of existents into systems. Since the theory is able to explore possible organisation of systems from a set of existents, it provides the means of understanding and communicating the system life cycle. The tool therefore also allows the exploration of what systems are possible and under what mix of existents. Importantly the theory gives important insight into its (and that of other similar tools) for *à priori* or *à posteriori* understanding and communication of systems.

Due to its observation of existents, the theory implicitly asks how such existents can be observed on analysis. It becomes apparent that no analysis of existents is possible unless the observer (analyst) has a reactivity for the existents being observed[200]. It is apparent from our discussions so far that tools can provide the observer with the reactivity that the actor does not have inherently. It is

[200]It is important to point out that Ashby raised a similar point that the "product space" of possibilities represents the "uncertainty of the *observer.* The product space may therefore change if the observer changes; and two observers may legitimately use different product spaces within which to record the same subset of actual events in some actual thing. The 'constraint' is thus a *relation* between the observer and the thing; The properties of any particular constraint will depend on both the real thing and on the *observer*." (Ashby, W. R., "Principles of Self Organizing System" in von Foerster, H., and G. Zopf, eds., *Principles of Self Organisation*, Pergamon Press, Oxford, 1962, p. 257-258). It is also important to recognise that at least in the context he said this, Ashby did not imply a commentary on observation in general. It may also be pointed out that Ashby therefore believed that "the theory of organisation will be concerned with *properties that are not intrinsic to the thing but are relational between the observer and the thing*" (p. 258). It may also be pointed out that to Ashby the word organisation connotes "conditionality" (p. 255). He therefore identifies organisation if "the relation between two entities *A* and *B* becomes conditional on *C*'s value". It is natural that Ashby therefore think that the converse of organisation is "reducibility" which has "parts whose actions are *not* conditional on values of other parts" (p. 256). This definition, as can be recognised from the foregoing arguments in this treatise, arises as a consequence of Ashby's bounding systems physically. Physically demarcated systems are however only a special case as the concept of organisation as used here has indicated.

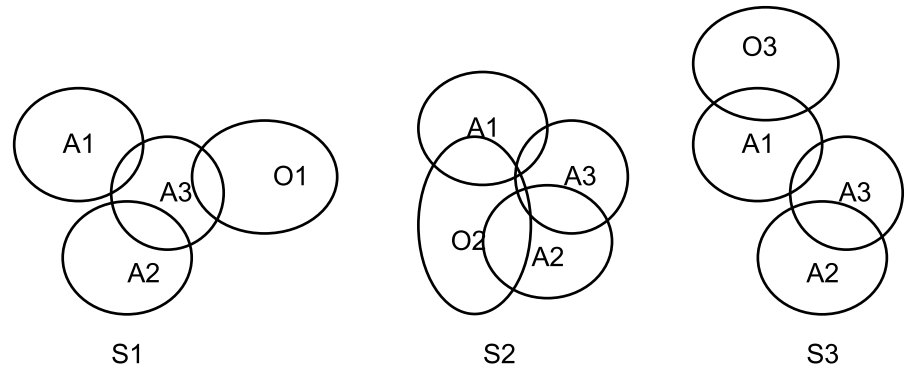

Figure 14 *A "Venn" representation of an observer of a system forming new systems during the observation.*

therefore logical to expect that tools that do not have inherent limitations in observation form the basis for conclusions.

Contrary to expectation, however, understanding and communication are based on experimentation or analysis both of which stress on the importance of observation in the form of experience and sense. As was pointed out above the observer as the analyst or experimenter is usually not isolated from the system the observer observes (See Figure 13). It must not be reiterated that *no* observation is possible without a *reactivity* to something being observed.

Let us consider three broad possibilities of observation: The observer observes an actor being modified (as the modification is crucial to the relationship defining the system) and is oblivious of who modifies and why (S1 in Figure 13). The observer observes both the modified and modifier actors in a system (S2 in Figure 13). Finally the observer may observe an actor modified but who is inconsequential to the system modifying it (S3 in Figure 13).

Conclusions drawn by the observer O1 will relate to a particular history of A3. O1 is in no position to draw *any* conclusion about the repeatability or even the dynamics of A3. For O1, the system S1 does not even exist. O1 is oblivious of the existence of A1 and A2.

O2 has the possibility of identifying A1, A2 and A3. O2 probably defines the system under observation or study as consisting of A1, A2 and A3. O3 is probably able to identify the reactivities of A1, A2 and A3 but can mistake the inscripts. So long as O2 has no inscript that modifies the event classes defined by A1, A2 and A3, O2 can draw reasonable conclusions about the *potential of the system*. O2 is however not in a position to assert the realisable and realised potential on the basis of observation alone.

O3 is like a person familiar with exponential curves observing chess. Such a person can notice the exponential decrease of chess pieces and conclude that is what chess is all about. O3 in having a reactivity to A1 and A1 being modified by A2 but not having a reactivity to the modified A1, fails to note S3 or even the irrelevance of the observed A1 to S3.

The "evolution" of our understanding of the earth in relation to the solar system is a characteristic case illustrating the limitations of "knowing" through observation. While Potelmy was completely right in his conclusions about geocentricism from the *reactivities* he had to observe the universe in about 151 A.D., newer reactivities gave rise to new observer-universe systems in the form of Copernicus's solarcentric theory (1543). As newer reactivities added on, Bruno (1548-1593), and later Galileo Galilei[201] (1610) and eventually the church (18??) and now we could observe actors in the same way.

Clearly what we see is not what it *is*. What we see is what we have reactivity to. With the theory it is possible to list observed existents and the observer too. It thus becomes possible to draw conclusions about the system with consideration for the analysts intervention and limitations.

Synthetic Systems

Using the theory of organisation of systems it is also possible to understand organisation and change in systems *à priori*. Using Syslogic it is possible to understand change in systems *à priori.* This means that observation of a system is *not* necessary to understand it. This does not imply in any way that observation is unimportant, it merely states that it is not essential. Just as the properties of acids and alkalis are known to the chemist from knowledge of the interacting ions without need to resort to experiment each time, the properties of a synthetic system can be understood without the need to resort to experiments or observation.

Such understanding follows from the use of the theory in a manner similar to applying Pythagoras theorem to a *specific* right angle triangle. It is not essential to experience every triangle to verify or understand another. The idea of drawing *à priori* conclusions about the real world is not new. As was pointed out in chapter 1, this forms an important tool for drawing conclusions about the world[202]. Several scientists have striven hard in their efforts at understanding and communicating their subjects *à priori*. *À priori* understanding is however possible only when a tool that operates on the domain facilitates such an operation.

A system follows from actors or more generally existents in much the same way as a molecule from atoms and triangles from lines. In much the same way as angles and lengths of lines can be varied to construct a triangle, so can reactivities or inscripts of actors to construct systems. It is thus possible to construct a system before observing or encountering it.

Let us consider how this is done with an example. Let us consider a system of three existents (actors). Let us call actor 1 as seller, actor 2 as buyer and actor 3 as good. If the seller and the buyer are given

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[201]It is interesting to note that Galileo Galilei is sometimes referred to as the father of "true" experimental science (Trattner, E., *Architects of Ideas: The story of the worlds great thinkers*, The New Home Library, New York, 1942p. 38).

[202]For example Lakatos (Lakatos, I., *Proofs and Refutations: The Logic of Mathematical Discovery*, Worrall, J., and E. Zahar, Eds., Cambridge University Press, Cambridge, 1976, p. 70-72) illustrates the process of simplifying secondary propositions into simpler propositions. In order to derive the mathematical relationships between the edges, vertices and faces of polyhedra, rather than base reasoning on polyhedra as the starting point, he attempts to simplify a polyhedra. In order to do so, he describes polygons as a system of polygons consisting of a single polygon (monopolygons). He then states that polyhedra are a system of polygons which have more than one polygon (polypolygons). He also concludes that by definition for a single vertex V=1. He thus "proves" by definition of an edge that V-E=1. He further "proves" that for a polygonal system V-E=0. By fitting two polygons, he shows that there will be an excess edge (E-V=1). Further as increasing a new face increases this excess by one E-V=F-1 or for polyhedra V-E+F=1. He further argues that the premises are not based on any *à posteriori* reasoning.

reactivities to the good, they will organise into a system (Following the theorem that actors with reactivities to a common actor organise around a relationship to constitute a system). We thus have a synthetic system which we can call as the market system. We are already in a position to identify the potential of the system, irrespective of what inscripts we attribute to each actor synthetically. The search for the realisable and realised potential of our synthetic system is based on a synthetic bound by an external actor (the good in this case could be the external actor, which indifferent to who transacts it, can spoil as it could be a biological product) and synthetic decisions of choice.

In the absence of the tools described in part 2, it was not possible to construct a synthetic system. The tools in existence provided no building blocks to construct a system in such a fashion that just as water is water or H_2O universally, the system constructed will be universally identical.

The very important implication of this ability is the possibility to resolve the issue of the observer as an actor controversy discussed above. This question, which has been raised several times in the context of quantum theory as with others, is that in observation the observer actually participates in the system and modifies it in the process of making measurements and isolating the system(s) of interest. In a synthetic construction of the system no modification of the real world takes place. It is therefore possible to avoid conclusions through observation that are a consequence of the observation and not a true behaviour of the system or its participating actors.

Another important implication is in terms of the dynamics (or the life cycles) of systems themselves. Typically “laws” of phenomena “discovered” through experimentation (observation) are expected to be acceptable if they put forth a condition for falsification. However usually the system is not bound, therefore the life cycle of the system itself cannot be studied. Why is that so important? Any “law” discovered through experimentation is usually the set of inscripts in the system. Changing the system normally implies the inscripts change too. The dynamics of inscripts also depends on the system defined by the script writer[203] (which could be a self aware or a error making actor). Unless the dynamics of the systems is taken into account, it is not possible to recognise the bounds of the validity of an observation or a law based on observation. Synthetic systems provide the possibility to explore “laws” in the synthetic system and the bounds (conditions and duration) over which they apply.

Self-Awareness and Learning

Both Syslogic and the theory of organisation of systems add to the reactivity of the analyst, observer or student of a system. With the clear recognition of the constant (actors and reactivities) and variable features (inscripts) in a system, observation can focus on elucidating the constants with greater accuracy rather than crave for precision in the variables. It is thus possible to identify and communicate a system in uniform and unambiguous fashion.

[203] A script writer is simply an actor responsible for creating an inscript for an actor in the system. In self-aware systems actors could be their own sript witers. In other systems inscripts would be written by for an actor by another actor.

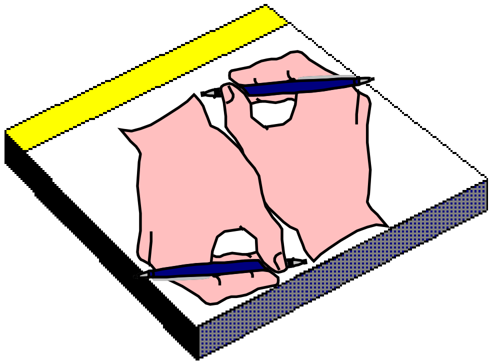

Figure 15 *Self awareness according to Escher.*

The use of a tool to understand and communicate a system that one is a part of creates a self aware system. Self aware systems, as was pointed out earlier, have reactivities to their own reactivities and inscripts[204]. This implies the possibility to switch between exercising a selected set of reactivities to another (thus accumulating with reactivity to some characteristic turned on or off). Such systems therefore have the *potential* to form several transient systems in a constantly reorganising world. The burden of self awareness is the also the freedom to choose the purpose. If as Georgescu-Roegen says that we are free if we can will our motives[205] then self awareness lends us this freedom.

Creativity is possible through self awareness. A creative response is the ability to choose a set of reactivities for participation. Such creative responses form the basis of management of organisation. Contrast this with experience which provides the possibility of change management through the changes in inscripts.

In practice when modelling such a self-aware system, for the sake of comprehension, it is often necessary to examine each transient system rather than the series of systems at once. In modelling such systems the reactivities to reactivities, naturally, need to be represented.

Learning, in contrast to self awareness is the ability of the actor to add *new* reactivities[206]. The failure to add new reactivities is the failure to learn. Learning does not necessitate awareness, but simply requires a means of accumulating reactivities or replacing old ones. Reactivities continue existence in memory (if such is possible in the system). Memory is therefore a systems collection of

[204]To borrow Minsky's example (Minsky, M., *The Society of Mind*, Simon and Schuster, London, 1986, p. 152) and explain it with the theory of organisation of systems, if you smile and you know you can smile you are self aware.

[205]Georgescu-Roegen, N., *The Entropy Law and the Economic Process,* Harward University Press, Cambridge, 1971, p.179.

[206]It may be useful to remind ourselves of what reactivity is here. Reactivity is the actors☝ ability to recognise ☝ and respond to an event☝. Actors can recognise the same events but respond differently. Actors can also react identically to different events. When actors recognise the same event and respond identically then they can be said to have the same reactivity.

reactivities[207]. Not all reactivities need be serviced in parallel. Thus memory provides the possibility to allow the system to organise in different ways. Memory is unnecessary for organisation but when present provides a wide store of potential organisations.

Environment

Everything sits in something; the something has been referred to as environment. The environment is an unbounded and loosely defined system. Often environment is used as a synonym for nature or the world. With the focus on interconnectedness and whatever can be measured, the events of concern for the environment, for example global warming, are usually far removed in time or space from the actors. The efforts of raising environmental concern are in effect creating a reactivity to the issues of the environment. The consequence is that understanding and communicating environmental issues is difficult. It is hardly any surprise that managing the environment is therefore illusive. We have observed earlier in Syslogic that it is sufficient for an actor to have respond to only those event classes that affect desired event profiles. It is thus quite unnecessary to burden the actors reactivities with newer reactivities to newer event classes. The principles of management, described in the next chapter, are (naturally) also applicable in the management of the concern for events attributed to be "environmental".

Syslogic and the theory of organisation of systems create the possibility to make the idea of environment uniform and well defined. For the actors, *it is the system that is the environment*[208]. Equipped with tools to understand systems we are equipped with tools to understand the environment. With the possibility of understanding (and communicating) the role of actors in a system, it becomes possible to create self-aware environments. When such self aware environments write their own reactivities, they create a potential for reorganisation on encounter with other actors (systems). Such self aware environments can then reorganise into alternative systems with different potential realisations.

It will be apparent that these tools already offer the possibility to reorganise systems and bring the ability for *every* actor to make a difference. In human societies, these are the tools that can help the citizens do things right and not just do the right things.

Hereditary and Evolution

The theory of organisation of systems identifies building blocks of systems that organise or reorganise with respect to each other as a consequence of their combined reactivities. Such a reorganisation of systems is irrespective of the *physical* nature of the building blocks. Such reorganisation is also independent of any *teleology* other than satisfying the reactivities.

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[207]Depending on the physical nature of memory, memory could be reactivity. For example a protein on a cell surface may constitute memory of exposure to some antigen and be the reactivity to the antigen. Thus the presence of reactivity implies the presence of memory in these systems.

[208]It follows from this and the preceding paragraph that *global* action is unlikely to be the best strategy to combat undesirable "environmental" changes. All acts are essentially in the context of a system and are dictated by the inscripts of the actors within. Extending systems by providing newer reactivities, as is done in some environmental issues, burdens the actors with the need to respond to events *downstream* rather than remove causes upstream.

Organisation proceeds according to the *active* reactivities of the interacting actors. It also proceeds according to the *encounter* of actors with reactivities.

It is therefore clear that the concepts of inheritance and evolution thus obtain a new perspective. It is clear that evolution is *reorganisation* of interacting systems. Reorganisation, as we have seen, proceeds when new reactivities develop or there is new encounter. Any system which can learn is then, by definition, capable of evolution. If any system can encounter new actors (or systems) then it is capable of reorganisation. If no changes in reactivities were possible and no new encounters could happen, then evolution would be impossible.

Depending on the *physical* nature of a system it can obtain new reactivities by learning and storing the reactivities in memory[209]. Such accumulations of new reactivities, irrespective of whether or not they are accumulated by learning, design or inheritance, can be referred to as reorganisation of *the system*. These changes normally involve and usually also result in consequent reorganisation of the interacting systems[210]. The reorganisation of interacting systems is evolution. The concept of evolution then is simply a statement of why things change the way they do. As this is a proposition about change of interactions between a group of systems, it encompasses all systems. This general proposition on evolution that follows from the theory of organisation of systems thus encompasses all systems, known and unknown, irrespective of their physical nature[211].

It will already be apparent that reproduction is not a *pre-requisite* for evolution. Reproduction is the ability of a system to *organise* elements to resemble itself. It thus provides the possibility to extend a similar system well beyond its own “life-time”. Reproduction itself can be achieved by organising elements with the complete set of reactivities of a system at a particular time (literally cloning) or by organising elements with enough reactivities to organise themselves to reassemble itself. If one considers “the system” as the simplest organisation from which evolution takes place, reproduction strives to sustain this system. Inevitably this system develops or evolves (depending on the physical nature of the processes). Reproduction can thus be viewed as a process that is *organisation sustaining*[212].

[209]The genetic material of biological systems can be considered memory of the system. This process may or may not be the same as reorganisation of the interacting systems.

[210]If this process does not involve reorganising the interacting systems, it can be referred to as development. On the other hand if it does involve reorganisation of interacting systems, development and evolution are the same for such a system. The consequent reorganisation of the interacting systems (if any) is evolution.

[211]Thus the concept is applicable to computer viruses as much as it is to cultures or even molecules interacting in test-tubes.

[212]Typically we tend to look at systems which are already products of much reorganisation to express the idea of evolution. While this is a valid viewpoint, it misses the continuous reorganisation of the system or the interacting systems. It is well known that ontogeny recapitulates phylogeny in biological systems. Unless it was the cell which was to be sustained, there is no reason to evolve a strategy whereby phylogeny (series of reorganisations of the system) are recapitulated. It would be easier to reassemble the reorganised system that is to be sustained. If reorganisation is the way of the world, then reproduction is the process to sustain an organisation. The reorganisation of an egg to a bird or an embryo to an elephant is because during the process or reorganisations the *reactivities have sustained themselves* as memory. An interesting example of reactivities *sustaining* themselves is found in the human immune system. Irrespective of the antigen the human is exposed to, the immune system can develop an antibody that is capable of “neutralising” the

It is almost needless to remark that evolution or even reproduction are not dependent on awareness. Awareness, however, when present can alter the direction or the strategy of evolution or reproduction. It is evident that memory plays a crucial role in sustaining a system whose strategy is reproduction. It is memory that makes possible the inheritance of reactivities. If the entire memory of a system can not be assembled in reproduction, the reactivities contained within are permanently lost unless the newly organised system can go through the series of organisations of its "parent" that allowed it to acquire the reactivity.

The destruction of reactivities (or memory) is tantamount to destruction of evolutionary (reorganisation) potential. It is therefore obvious that stable systems have little or no memory and few reactivities. It is also evident that systems with widest possibilities have huge memories or many reactivities. The introduction of reproduction is a means of sustaining organisation. Depending on the amount of reactivities that can be reassembled through memory, evolutionary potential can be increased, decreased or kept constant. It is needless to remark that these considerations weigh heavily on the principles of systems design.

In a reorganising system of actors it is important to recognise that the universe is co-evolving. The reactivity-driven organisation is therefore responsible for the organisation at any moment of time. It is the burden of self aware actors therefore to *co-evolve* with their partners in this co-evolution.

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antigen. At the same time subsequent exposure to the same antigen produces a faster neutralisation process. A reactivity to an "unknown" antigen can thus develop and sustain itself.

Chapter 6

Management

Syslogic

Syslogic allows to differentiate three levels of management: management of states, the management of change and the management of relationships. Each level of management is an attempt to alter certain characteristics of the system that are crucial to the "manager" who practices management at either of these levels. While in principle what follows applies across the domain we have been considering, it has been written with examples of systems of humans as actors owing to their immediate importance and familiarity.

The Management of States

As pointed out earlier, Syslogic views a system as comprising of actors engaged in a relationship. Each actor attempts to "manage" the relationship through appropriate decisions in response to events[213]. Such a manager[214] relies on event correction to obtain conditions desired for the manager. Such managers are *driven* by events and therefore their management of states can also be referred to as *event-driven management*.

An inventory manager driven by the event of a shortfall of an item will decide to order the item. In a similar fashion a thermostat driven by the achievement of desired temperature decides to shut off the heating (cooling).

The event-driven manager is focused on the (un)desirable event(s). As pointed out in the previous chapter, such an actor is oblivious to the existence of any system. If such an actor does recognise the acts of other actors continuously causing the (un)desired events then the response is to treat these acts of other actors as events themselves. The natural subject of management then becomes things and other actors. It is important for such managers to *act* rather than not act in response to the trigger event.

The focus on (un)desirable events drives such management to invest in early and more sensitive event monitoring systems. It is the hope of such managers that early detection of (un)desired events is likely to have greater success in managing the event than otherwise. The typical examples of such

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[213] It is interesting to compare these observations with Beer's Viable System Model (VSM). The "system ONE", for example, of Beer's model can perhaps be described as actors driven by events (Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, p. 130, 176).

[214] Every actor by the acts of modifying something is a manager. Management science and business communities generally consider only the special case where the manager is someone who oversees other actors.

management with increased sensitivity and event monitoring systems are traffic control, disease scanning, espionage, project management and fault tolerant engineering design.

The management of states is met with success under certain conditions. The first precondition for success in the management of states is that the system must not have more than one actor responding to the same event class[215]. In the event that more than one actor responds to the same event class, it is necessary that they do not respond to events in the event class in different directions. For example the Romanian government removed all forms of birth control to respond to dropping family size. The people responded to growing family size by resorting to illegal and dangerous contraceptives. As another example consider the inventory manager ordering at the shortfall of an item. If the production manager responds to the availability of the item by consuming it, the inventory manager will always be found ordering the item!

If the event class being responded to is (also) affected by another event class not managed by the actor, Syslogic identifies the situation as the actor lacking an *adequate* role in the system. It is obvious that the event-driven manager will have limited success in such a system. Sometimes such an event class can be the result of the dictate from an indifferent actor. For example the stock of water in a reservoir is affected by the release of water out of the reservoir as well as the emptying of another reservoir managed by another actor into the reservoir. Another example of the lack of adequate role is that for an actor attempting to decrease the consumption of goods by increasing prices. Consumption also results through increased income of the consumer which is not managed by this actor attempting to reduce consumption.

The event-driven manager needs to revise the events responded to whenever the relationships between the actors change. For example if a borrower and lender continue to exchange money but with the lender developing a close interest in the welfare of the borrower, new desired event profiles will be set up. The manager needs to be able to respond to these newer event profiles in contrast to existing ones. If the system itself reorganises so that there is no longer a relationship between the lender and the borrower (perhaps because there is no more a monetary system) the manager will need to be able to develop a role in the reorganised system.

The Management of Change

Syslogic points out that change as visualised by a participant in the system is the change in events that occur *in* the system. While it is important to respond to change as the event-driven manager does, it can be useful to formulate inscripts that can drive the system towards desired event profiles. Managers of change therefore attempt to provide the event-driven manager with inscripts to respond to events in order to obtain a desired event profile[216].

[215]It may be pointed out that we know from the theory of organisation of systems that such a "system" is impossible as there can be no system unless there is a shared event class (if one were to mix the jargon of Syslogic and the theory of organisation of systems).

[216]This role can perhaps be compared with the role of what Beer calls "system TWO" in his model of viable systems (*ibid*., p. 176).

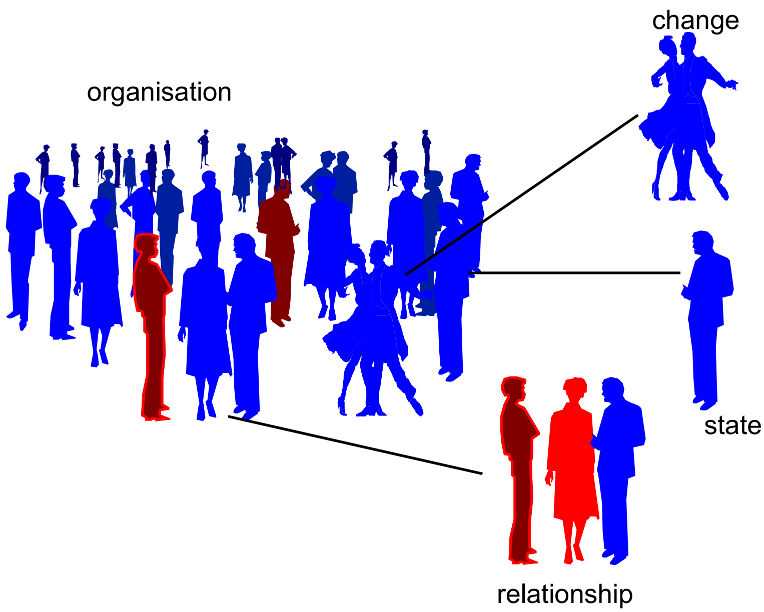

Figure 16 *The management of state, change, relationships and organisation in a human community.*

The focus on anticipation often leads such managers to create inscripts that respond to numerous events in each event class. It is the hope of such managers that the ability to react to every condition appropriately is likely to have greater success than if such capability did not exist. The typical example of such formulations covering numerous possibilities are social security in several countries, some of which recognise 64 ways of people staying together to decide the social security they are eligible for. Another example are the laws of taxation in several countries which are formulated to try to react to every possible and (nearly) impossible event.

Changing inscripts tends to shift the dominance of actors participating in a system. This is usually followed by a similar adjustment on actors who do not dominate now to allow them to dominate later. The system can thus continuously shift between different dominating actors.

Like other management levels, this too can meet with success under certain conditions. A prerequisite for the success of a change manager is the ability to anticipate the minimum events in the event classes that need to be responded to maintain a desired event profile. Another important precondition for the success of the change manager is the making explicit the purpose in each inscript. While it is important to react to an event identified in the inscript, the how to react has to relate to why to react. The inability of the how and why to match usually leads to undesirable consequences even with the managers who could anticipate every important event. Usually excessive possibilities being put into inscripts rather than evolving inscripts when the newly organised system requires them leads to such a failure of the how and why to match[217].

It is also essential that the change manager revise the understanding of inscripts whenever the relationship changes or the system changes. Normally the inscripts need to be rewritten under these new circumstances.

The Management of Relationships

In Syslogic a relationship involves the partitioning of some stock. The purpose of the relationship is the partitioning. Each participating actor may have own purposes about how the partitioning will work for that actor, but that is the actors purpose and not that of the relationship. For the relationship manager there is an explicit recognition that it is the relationships that need to be sustained to sustain a system[218].

A relationship manager is focused on the partitioning of some stock. Such an actor "manages" the continued existence of the relationship through a continued concern for the events that are caused by the stock being partitioned. This is possible by ensuring the (continued) ability to react to such events or through the provision of express inscripts to do so or both.

Advertising is a common example of creating the ability to react to events. Advertisements (and other media coverage) act as "tools" that extend the recognition of their audience to include the (new) events that are advertised[219]. A rule or regulation also expose an event they are framed to respond to. A typical example is the requirement of visas to travel across national boundaries. Whatever the purpose of such instruments, they also serve to expose the event of an national or non-national crossing the boundary of the nation. In the absence of such a regulation or inscript, it may be extremely hard to note the event of a national or non national crossing the boundary of the nation.

Like the other levels of management, the management of relationships can also meet with success under certain conditions. The first precondition to the management of relationships is the recognition by the relationship manager of the events that are important for a relationship. The next necessary condition for success of an relationship manager is the ability to equip the actors in the system with the tools to recognise the events. In the absence of these, the relationship manager cannot establish a desired relationship between the actors. It is important to reiterate here that a *relationship here implies only the purpose of partitioning some stock*. The direction of the partitioning is outside the scope of a relationship manager whose sole interest is the existence of such partitioning.

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[217]For example the EC laws prohibit the manufacture of engines which do not have a particular composition of gasses in combustion. This makes impossible for a "greener" technology the lean engine to be designed. The inscript with how rather than why lost the why it was required completely.

[218]Perhaps this is precisely what Beer implies in his "system THREE", in the VSM, which he typifies as the as "metasystemic" as it surveys the total activity of the operational elements of an enterprise (*ibid.* p. 202). "It is aware of all that is going on *inside* the firm *now*." Beer visualises this as being responsible for synergistic planning and visualises this role to be possible through direct "interactions" with "system TWO" (excess of which, he points as, being autocratic and responsible to annihilate the freedom of "system ONE"; *ibid*. p. 209, p. 214) or with "system ONE" (which, he points as, being autonomous; *ibid*. p. 210, 214).

[219]The functional mapping of advertisements is often invalid or inconsistent. Owing to their formulation, advertisements often make it extremely difficult for the lay audience to see the structural domain (premises) and the functional domain (conclusions) that are drawn in the advertisement.

Application

Syslogic can thus not only serve as a tool for exploring possibilities but importantly provide principles for management. Exploring the possibilities for managing the system through each of these levels in effect allows the manager to explore the possibilities to move towards realising a desired potential of the system. A set of theorems that concern the options to realise potentials can be collected as principles to achieve desired potentials.

It is also important to reiterate that while the usual use of Syslogic could be analytic to understand, communicate and then manage a system, it can also be used for constructing synthetic systems of desired characteristics. This is particularly useful in the *design* process as Syslogic provides building blocks for designing systems. With the possibilities for putting together building blocks that are familiar, and yet independent of any specific part of the real world, structures of all kinds can be generated. The impressive possibilities from a simple block are almost suggestive of its similarity with the building block of nature itself.

Theory of Organisation of Systems

The theory of organisation of systems allows to differentiate yet another level of management: the management of organisation. As pointed out earlier, the theory is a superset of Syslogic. It is therefore possible to rephrase the observations on the three levels of management differentiated by Syslogic from the premises of the theory and thus in the jargon of the theory.

To summarise briefly: Each existent by virtue of its reactivity attempts to continuously react to other existent(s). This is only possible if the existent being reacted to is in a state that can be recognised. The reactor is thus driven by "events" or the characteristics of the reactant. The reactor is thus an event based manager or the manager of states. The reactor through the ability to modify another actor in different ways acts as a change manager. The reactivity of the actor defines and dictates what the actor can react to. By deciding the reactivity, an actor manages the relationships that can be engaged in.

The Management of Organisation

According to the theory of organisation of systems, on encounter actors with reactivities to a common actor organise around a system to constitute a system[220]. Central to the management of organisation is therefore encounter and reactivity.

An *organisation* manager recognises the event profile of the system being managed is a consequence of the way it is organised. It is therefore important for the organisation manager to understand, anticipate and even shape the organisation to avoid undesirable event profiles. The organisation manager is therefore concerned with making (im)possible the encounters of the actors with a

[220]As we have followed Beers VSM closely so far, the and it is only appropriate to point out that the role of his "system FOUR" or "outside and then" (*ibid.*, p. 251-259) can be likened to anticipating the organisation resulting from possible encounters with other existents. Beer describes a "system FIVE" for what he calls as "logical closure". The role of "system FIVE" is "*identity* and self awareness" (Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989, p. 25). The theory of organisation of systems defines a self aware system as one with reactivities to its own reactivities. As pointed out by Beer, a system without "system FIVE" can be identified as living. The reactivities to the reactivities on the other hand are crucial for the system to be viable.

particular reactivity to each other. The organisation manager also spares little effort in understanding and managing the reactivities of the actors in the system.

To the organisation manager, nothing can be static. Not even the organisation. Embedded in the constantly reorganising world, the organisation is constantly under change. The organisation manager is therefore a true change manager.

The management of organisation is met with success under certain conditions. The first precondition for success is the ability of the manager of organisation to be able to form stable complexes with the existents whose encounter is being organised. Without this the manager is not in a position to organise encounter. The organisation manager must be able to write the reactivity or inscript of at least one actor in the organisation to be able to alter the organisation. As discussed earlier, in a self aware actor the actor can alter the reactivity of the self.

Examples of organisation management that we are familiar with are chemical processes. The chemist with the knowledge of the reactivities of the individual atoms or molecules can design molecules of preference. The chemist can also engineer the reactivities of the molecules or atoms by changing temperature or pressure or introducing a "catalyst".

Application

The theory of organisation of systems leads to basic management principles about possible and impossible organisations. This opens the possibility to predict the formation or break-up of an organisation in mathematical precision in a shareable and explorable fashion. Since the elements of organisation are existents which can be given synthetic properties *à priori*, it is possible to design and explore the life cycles of organisations *à priori*. It therefore presents a possibility of deciding the management options *à priori*. With the general principles of management that can be derived from the structural domain, such a tool offers the possibility of deriving newer principles for synthetic situations *à priori*. It is therefore not necessary to experience a system to be able to manage it effectively.

Designing Systems

It is apparent that unless specifically designed to organise otherwise, organisations organise by the sheer momentum of the reactivities of the actors in encounter[221]. The need to design organisation is a natural consequence of the desire to encounter a particular *tomorrow* (or a particular organisation). In such event it is inevitable that there is need for principles of design which can be elucidated from the starting point of the theory of organisation of systems. Many such principles can be listed and the attempt here will be to both point out the relationship of such principles to the physical nature of the existents being organised as well as some of the principles that need to bear heavily on theorems about evolution, development, sustainability and change. It is beyond doubt that *building blocks* of organisation can contribute to the fundamentals of such design.

Automation

One of the privileges of awareness is the ability to design systems. Managers of systems, especially the organisation manager attempts to design systems in effort to manage the system. The principles

[221]Try organising a get together for a group of people who hardly know each other. Those who are at least acquainted will tend to stick together unless there is a deliberate forced encounter or individuals have reactivity to unfamiliar!

of design of all systems necessarily follow from the principles of organisation. Given the objective of designing organisations of certain stability or lifetime or with particular characteristics, the theory of organisation can be applied to design such organisations. In much the same way as compounds of desired characteristic can be designed by the chemist, the organisation designer can use the building blocks of systems in order to design systems with desired properties.

The tasks of designing automata (machines, computers, robots) are a special case of such design. It will already be evident that these design principles are independent of the physical implementations chosen for the automata. When these principles are followed it is possible to design such automata to exhibit desired properties of organisation, learning and awareness[222].

Computer hardware and software are special physical forms that can be organised and create organising systems using these principles. Perhaps the most interesting development in computer languages is the development of event-driven languages (sometimes referred to as "object oriented languages") where the programmer can be considered as a script writer for the event. For example the development tools for Microsoft Windows™, notably Visual Basic and Visual C++, provide the ability to write scripts to give Microsoft Windows™ the inscripts of choice to respond to events of the keyboard, mouse, timer. It is no surprise therefore that it is possible to have programs organise into patterns under this environment in ways unthinkable under DOS. An extension of these ideas to include the principles of organisation can provide any language to help the script writers and the users (as the interacting actors) to organise in desired learning or even self-aware systems.

Change, Sustainability and Development

Syslogic identifies at least two kinds of changes: changes in the events experienced by the system and changes in the relationships within the actors in the system. As discussed above, the manager of the states is concerned with the former and the manager of relationships with the latter. As a consequence the manager of the states wishes to *sustain* an event profile whereas the manager of relationships is concerned with sustaining the relationship. Sustainability thus acquires not only a new perspective, depending on the level of management, but also a practical and achievable operational meaning.

With the theory of organisation of systems we can recognise that nothing is permanent. Not even relationships. With everything, even relationships changing (despite the relationship manager) it becomes important to understand if the newly organised system can sustain the actors of the earlier system with a new role. With this comes the new focus on an practical and operational concept of change management that is concerned with organisation in a completely dynamic fashion. The idea of permanence or statics is completely done away with. While the systems change and organise, it then is important to find new organisations that can sustain a humane role for the participants.

With the theory of organisation of systems, it becomes clear that the goal of sustaining a system is at the cost of *change* and *evolutionary potential*. In practical terms such sustenance can be realised by either isolating a system, by selective destruction of the memory of the system or even reproduction of the system to be sustained. The obvious question is *why* sustain and oppose the

[222]The efforts of "artificial intelligence" or "machine intelligence" (as some prefer to call it) have concentrated on "intelligence" and physical "resemblance" to human organisation (for example neural nets). While there seem to be "advances" in some tools of AI to achieve some characteristics of a desired behaviour, there appear no building blocks capable of independent existence that can generate all desired characteristics through assembly.

change? We have observed that the process of reorganisation reorganises old systems when *new* encounters take place or when *new* reactivities develop. While this is the only possibility for the participants of an system to explore change, it can still pose the threat of organising into undesirable organisations. The only possibility out of the dilemma of sustainability is then to have self aware systems that can *co-evolve*. This means that there is an need to distinguish change that reorganises an actor with change that reorganises a system. While the former is undesirable from the viewpoint of actors, the latter should certainly be welcome as offering a possibility to create new potentials for realisation.

The question of development can similarly be resolved as a consequence of the theory of organisation of systems. We identified in the previous chapter that development, in contrast to evolution is the reorganisation of the system itself as a consequence of having accumulated (or shed) reactivities. Development usually alters the evolutionary potential as a consequence of the alteration of the reactivities. Development is thus unlikely to sustain the ability of the system to sustain itself. If sustaining the system is the goal, development is *potentially* counter-productive. However, development is the only way in which new evolutionary potential comes to be part of a system. If creating change is important, development is mandatory. It is important to note that in the choice of development, the system invariably sets a self destruction process rolling.

The possibility out of the dilemmas of *sustainable development* are again to be found in creating self-aware systems. Such self-aware systems can then choose development and sustainability as appropriate.

Eavesdropping

"Ah ha! At last what we can do!"

"There speaks the man of action.."

"This opens up so many things I had not dreamt up before..."

"How often I have tried to understand relativity of experience, and here.."

"In Friesland[223] we say 'They look at my drinking, but no one knows how thirsty I am'!"

"Perhaps this is some tool to share experiences then!!"

"I always thought observation was the absolute...but I'm beginning to rethink.."

"Not only is it relative, but you see only what you have reactivity to.."

"All that vocabulary I have been using... 'problems', 'fact', 'right', 'wrong' ...."

".. don't do yourself injustice, you hardly looked at the world in this fashion before."

"Then it hardly makes sense for me to build up the database on performance?"

"No, no. It sure is a historical record which serves other useful purposes."

"Don't decide on history. You only recreate it!"

"I always wondered if we could figure a way to find out what can change the performance of the system."

"You have it there. Don't blame those poor guys struggling ..."

"...when you may be the external actor dictating things?"

"But I like the theory even more..."

"Yes. Those reactivities he leaves us with..."

"Strategic, tactical and operational reductions are just not necessary. Competition is redundant..."

"And those insights of Forrester and Beer and the others are still preserved..."

"Naturally! Every tool can see within its scope."

"Those management categories..."

"..management of the state, change, relationships and organisation.."

"Yes, those. I can see how much management resting at one level alone leads to consequences we call problems.."

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[223] A province in the north-eastern part of the Netherlands.

“.. and try to manage them using the same level when another was required!”

“..and to these tools as building blocks!”

“It is organisation that litteraly defines tomorrow!”

“I must say this is all down to earth after all.”

“Literally a toolbox for tomorrow...”

Epilogue

The toolbox provides a means of structuring knowledge into a *single* consistent framework. It can therefore be viewed as a classification scheme that minimises redundancy. Providing a means of defining the context for observations, it provides a means to *share* experience in mathematical precision without loosing the relativity of reality and without sinking into the subjectivity of description. It therefore provides a sound basis for "what if" explorations that can be communicated and used for decision support. The toolbox also complements traditional science lending an explicit framework to distinguish change within a system and change of a system.

The toolbox provides an *à priori* basis to generate principles for management and design. This means that such principles can be free of specific cases or observations. This implies that the toolbox can provide ground for action in ambiguous situations or in the absence of observation. As the tools within the toolbox are free of the physical nature of the reality they apply to, the tools can be used equally to design software as to manage institutions.

As pointed out in the prologue we explored the two tools of the toolbox: Syslogic and the general theory of organisation of systems. Syslogic offers the possibility to describe systems in terms of the actors. Since actors are the only constant things in a system, it offers a way to share understanding about systems. It is easier to explore the nature of management to realise desired potentials when one can explore what realisable potentials exist in different *isoforms* of the system. The possibility of moving towards the desired potential through a response isoform can be contrasted with reactive isoforms.

In Syslogic, every event relates to an event as understood by the actor. It is therefore possible to explore the "world" of an actor. Syslogic offers a powerful tool to communicate the *relativity* of experience, especially in its implementation in the form of the *visible toolbox*.

Having succeeded in pinning down a system, it becomes possible to operate on change *within* the system without the danger of irrelevance. The sustenance of relationships forms the basis for Syslogic's operation on the system to sustain the system.

Syslogic is thus a major step forward in being able to *share* understanding of a system, explore the potentials for change, understand and communicate relativity of experiences, explore the event profiles under specific conditions and even manage change and sustainability *within* the system.

The newly developed general theory of organisation of systems presents a *building block* of organisation, *irrespective* of the physical characteristic of the organising substance. The importance of this tool hardly needs emphasis. Not only can such building blocks help to explain existing organisation but also design to new organisation.

Considering the rate at which the systems of the twentieth century have organised themselves with the sheer momentum of the reactivities of their participating actors, it is the urgent and immensely important need for human systems to be organised with at least a partial awareness to this process of organisation. It is important to reiterate that the organising systems that concern us here are not human systems alone. Organisation of all systems irrespective of their physical nature concern us in to understand, communicate or manage the environment. The accumulating reactivities can sustain or destroy the human race (and much else) depending on how tools of organisation are used. The general theory of organisation serves as a tool for organising newer and sustainable systems.

With the ability to trace the life cycle of systems, it becomes possible to explore the formations and reorganisations of the existents that make up a system. The scope of operation extends well beyond the lifetime of organisation of a system to truly encompass all change within and without the system. Sustainability presents itself as a sustainability of the existents in reorganising systems, ensuring that no existent is reorganised in the process of reorganisation.

These tools can be applied to *all* systems and organisations, known or unknown, irrespective of their physical characteristic. The tools can be applied for understanding, communicating or even managing the organisations and/or systems they operate on.

The tools within the toolbox offer to add to our reactivity the *reactivity* to reactivities. Equipped with such tools then we can literally create the possibility to write our reactivities. We are thus in the position to understand, communicate and manage even the tools that we began with. Organisation then can be what *we* choose as *individuals*.

The process of accumulating the tools that we went through in the three parts *rests* the treatise. In order to gain access to reactivities to reactivities, it was essential to equip you, the reader, with tools to give you the reactivity to the nature of tools in the first part. It may *now* seem obvious that the number and nature of conclusions of tools are bounded by the set of premises one accepts. This important accumulation helped create the reactivity to the constantly changing world we live in. Importantly it became possible to create a reactivity that can share our understanding, communication and management even in a moving environment. We made these important steps in part two.

What value is such reactivity? Action is what moves the world. But if the consequences of action elude us in an ever-changing world, can we hope to organise the world, or even the environments we belong to? We can then remain moved by the forces of our own actions to organisations that we do not ever desire. In part three, however, we accumulated the tools to help us to explore and communicate the world, to react to events, to react to changes, to respond to relationships and to respond to organisation. This precisely is the practice of these tools.

By eavesdropping on ourselves, we explored the process of reacting to our own reactivities. We complete a full circle. If it were possible this book should be circular. No. Spiral. For while we are where we were, it is at another level of recursion. With the reactivity to our reactivities. Self-aware and therefore complete. With the ability to *define* what organisation we desire.

The building block of *all* organisation, *irrespective* of its physical characteristic is identified. Such a building block provides us with the possibilities to understand, communicate and manage organisation. Even when it is changing, for organisation is always changing. With such building blocks we open the potential to organise physical systems in our surroundings in more humane organisations.

Along with the problem solution spiral, we have also abandoned the consequences of multiple mapping and the consequences of moving systems. Perhaps there is more that we have shed as we accumulate the new tools. Sustainability and the management of change in constantly moving systems is then what is possible. Equipped with our new reactivities that is the next task.

Appendices

A Technical Summary

Appendix 1 and 2 are restatements of existing tools to expose their scope. Appendices 3 and 6 are technical statements of the Toolbox. Appendix 4 summarises the language NOW and Appendix 5 describes the Visible Toolbox based on Syslogic.

Appendix 1

Beer's Theory of Viable Systems

The following is a *re*formulation of Beer's theory of viable systems[224]. The following *reorganises* some of Beer's statements and identifies the premises of his "Viable System Model" to make the structural and functional domains apparent. Beer has himself classified certain of his statements as aphorisms, axioms, laws, principles and theorems[225]. It may be pointed out that his axioms do *not* from the basis of his viable systems theory, but rather find themselves as the basis of the management principles he states (which can perhaps be better described as theorems). This does not decrease the importance of his observations but rather enhances our understanding of his theory. It becomes clear from this reformulation that Beer is concerned with systems within systems obeying Ashby's law of requisite variety[226] within and when exchanging information between subsystems and transducing the information.

Definitions

Variety: Variety is defined as the number of possible states of whatever it is whose complexity we want to measure[227].

Axioms

Variety manages variety[228].

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[224]For the original formulations see Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, Beer, S., *Diagnosing the System for Organizations*, John Wiley, London, 1985 and Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989.

[225]For a summary and index of Beer's aphorisms, axioms, laws, theorems and principles see Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, p. 565-567.

[226]Ashby's law of requisite variety states that only variety can destroy variety (Ashby, W. R., *An Introduction to Cybernetics*, John Wiley and Sons, New York, 1955 p. 207).

[227]Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, p. 32.

[228]This is nothing but Ashby's law. Beer himself states that the model of the viable system was devised from the beginning in terms of interlocking Ashbean homeostats (Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989, p. 17). It is thus Ashby's law that variety can manage variety that lies as the axiom of the VSM.

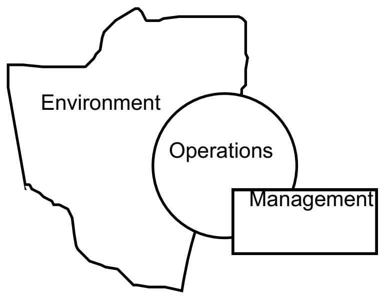

***Figure** 17 Management unit as embedded in operations which is embedded in the environment which in turn sits in a meta system as visualised by Beer.*

A management unit is embedded in the operations it regulates which is embedded in a loosely defined environment[229] *(See Figure* 17*).*

Laws

Information exchange between units takes place through channels[230].

Information exchanges through channels undergo transduction[231].

Theorems

Theorem 1: Managerial, operational and environmental varieties tend to equate[232].

Theorem 2: The four directional channels carrying information between the management unit, the operation and the environment must each have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating sub-system has to generate in that time[233].

Theorem 3: The variety of the transducer must be at least equivalent to the variety of the channel[234].

[229]Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, p. 94-95.

[230]*ibid*., p. 96-97. Beer points out that the consequent behaviour is what is novel about his approach (See Beer, S., "The Viable System Model: its provenance, development, methodology and pathology" in Espejo, R., and R. Harnden, eds., *The Viable System Model: Interpretations and Applications of Stafford Beer's VSM*, John Wiley, Chichester, 1989, p. 18).

[231]Beer, S., *The Heart of Enterprise*, John Wiley and sons, Chichester, 1979, p. 101.

[232]*ibid*., p. 97 "The First Principle of Organisation". It must be noted that Beer adds an important advise within his first principle: such equation of variety "should be *designed* to do so with minimal damage to people and to cost".

[233]*ibid*., p. 99 "The Second Principle of Organisation".

[234]*ibid*., p.101 "The Third Principle of Organisation".

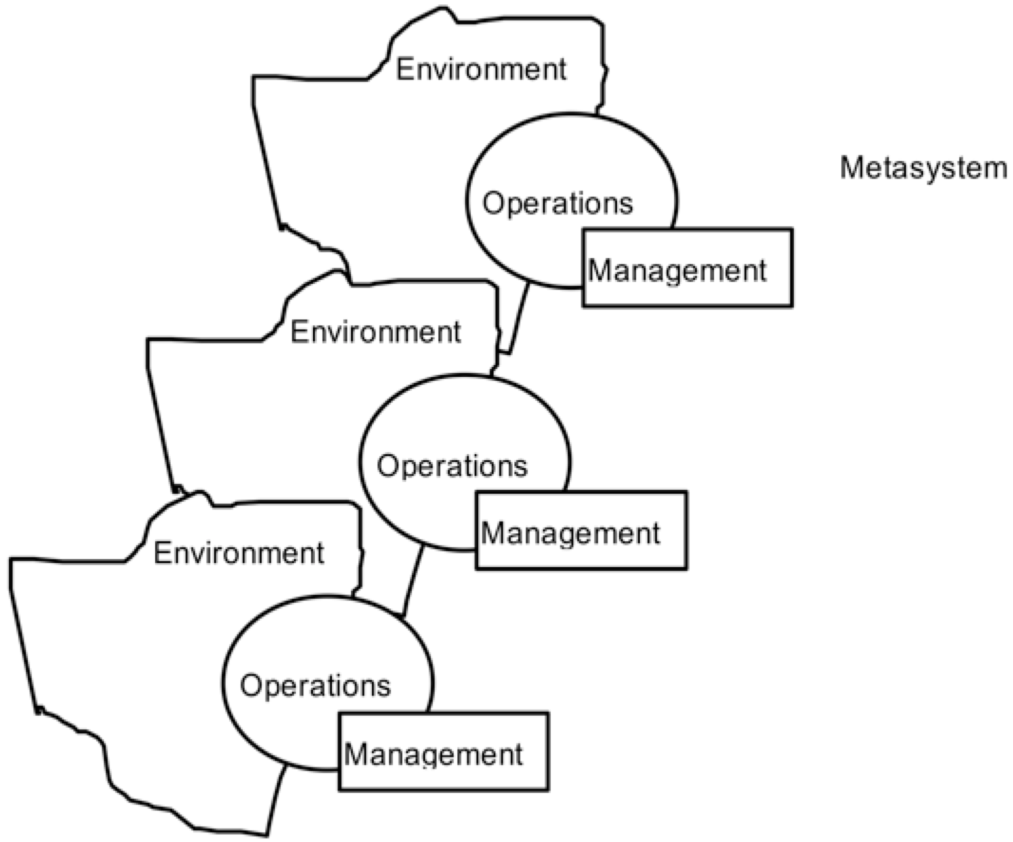

***Figure** 18 Recursion of viable systems.*

Theorem 4: In a recursive organisational structure, any viable system contains, and is contained in, a viable system[235] (See Figure 18).

Theorem 5: Every viable system needs a high variety attenuater to restrict the interactions between the management units of its subsystems[236].

[235] *ibid.*, p.118 "Recursive System Theorem".

[236] *ibid.*, p. 176-178. Beer refers to any unit that provides such a "service" as "system TWO", "system ONE" being used to refer to the subsystems that make up the "system in focus".

Theorem 6: Every viable system needs a metasystemic attenuater that can absorb the variety of the high variety attenuater and the interacting subsystems[237].

Theorem 7: The sum of variety deployed by system Three in the vertical plane equals the sum of variety deployed by elemental operations in the vertical plane[238].

Theorem 8: The sum of horizontal variety disposed by *n* operational elements equals the sum of vertical variety disposed on the six vertical components of corporate cohesion[239].

Theorem 9: Every regulator must contain a model of that which is regulated[240].

Theorem 10: Every viable system must have a balancing operation between the variety generated by “system FOUR” and that of “system THREE”[241].

[237] *ibid.*, p. 200-217. Beer refers to any metasystemic unit that provides such a function as “system THREE”.

[238] *ibid.*, p.211. Beer points out that “system THREE” can absorb variety through “autocracy” by attenuating the variety of the management of “system ONE” or through “autonomy” by distributing the attenuation between operational unit of “system ONE”, the management of “system ONE” and “system TWO”.

[239] *ibid.* p. 217 “The First Axiom of Management”. By horizontal variety Beer implies the variety along the environmental-operational-managerial axis. By vertical variety Beer implies the variety along all vertical channels or “system THREE” interventions, interactions between the management of “system ONE”, “system TWO” interactions and the interactions between the operational elements of “system ONE”.

[240] *ibid.* p. 234. This is Beers explanation for the necessity of the metasystemic unit “system FOUR” which serves this function.

[241] *ibid.*, p. 259. Beer refers to any metasystemic unit providing this function as “system FIVE”.

Appendix 2

Forrester's Principles of Feedback

The following is an axiomatic *re*statement of "Principles of Systems"[242]. This text *reorganises* Forrester's propositions about "systems" to state them to differentiate his premises and conclusions. Such a statement, then, allows the domain of System Dynamics to be defined precisely. Such a reformulation is meant to enhance our understanding of Forrester's theory and does not in any way decrease the importance of his statements. It becomes apparent in such a statement that Forrester is concerned with feedback loops and the dynamics of their interactions. These principles are therefore better described as 'Principles of Feedback' rather than "Principles of Systems".

Definitions

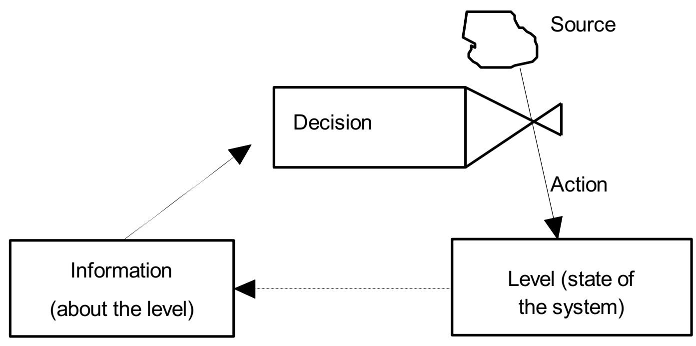

***Figure** 19 The Feedback Loop.*

- **The Feedback Loop:** The feedback loop is a closed path connecting in sequence a decision that controls action, the level or state of the system, and information about the level of the system, the latter returning to the decision making point[243] (See Figure 19).

[242]For the original formulation of the principles of "systems" (or more commonly known as System Dynamics) see Forrester, J. W., *Principles of Systems*, MIT, Cambridge, 1968. This remains the accepted statement of the field of System Dynamics and Forrester is still the accepted authority on System Dynamics that he developed.

[243]*ibid.*, p. 1-7.

- **Order of Feedback:** The number of level variables in the feedback loop determine the "order" of the feedback loop. Thus a feedback loop with only one level is an first order feedback[244].

- **The Sign of the Feedback:** A feedback loop is negative if the control decision attempts to adjust some system level to a value given by a goal introduced from outside the loop[245].

Axioms

Decisions as Part of Feedback: Every decision is made within a feedback loop. The decision controls the action which alters the system levels which influence the decision. A decision can be part of more than one feedback loop[246].

Feedback needs to be Dimensionally Consistent: In any equation, every term must be measured in the same dimensions. Terms having different units of measure within an equation indicate a faulty formulation[247].

Decision is Based on a Level or its Derivative: Only apparent or available information can influence a decision. "True" system levels are often altered by processes within the information network before they become available at a decision point[248].

Postulates

Feedback as the Building Block for Systems[249]: The feedback loop is the basic structural element in systems. Dynamic behaviour is generated by feedback. The more complex systems are assemblies of interacting feedback loops[250].

Laws

Levels Integrate: The levels integrate or accumulate the results of action in a system. The level variables can change instantaneously. The levels create system continuity between points in time[251].

Levels are Changed by Rates: A level variable is computed by change, due to rate variables, alters the previous value of the level. The earlier value of the level is carried forward from the previous period. It is altered by rates of flow over the intervening time interval. The present value of a level variable can be computed without the present or previous values of any other level variables[252].

---

[244]*ibid*., p. 2-3.

[245]*ibid*., p. 2-9.

[246]*ibid*., p. 4-5, Principle 4.2-1: Decisions always within feedback loops.

[247]*ibid*., p. 6-2, Principle 6.1-1: Dimensional equality.

[248]*ibid*., p. 9-5, Principle 9-6: Decisions (rates) only based on available information.

[249]This postulate connects ideas of feedback to systems.

[250]*ibid*., p. 4-6, Principle 4.2-2: Feedback loop--the structural element of systems.

[251]*ibid*., p. 4-7, Principle 4.3-2: Levels are integrations.

[252]*ibid*., p. 4-7, Principle 4.3-3: Levels are changed only by the rates.

Computation of Levels is Integrative and Methods of Integration are Applicable[253]:
Levels are Conserved Quantities: All levels are "conserved" quantities. They can change only by moving the contents between levels (or to and from a source or a sink)[254].

Theorems

Rate not instantaneously measurable: No rate of flow can be measured except as an average over a period of time. No rate can, in principle, control another rate without an intervening level variable[255].

Rates is a function of Levels and Constants: The value of a rate variable depends only on constants and on present values of level variables. No rate variable depends directly on any other rate variable. The rate equations (policy statements) of a system are of simple algebraic form; they do not involve time or the solution interval; they are not dependent on their own past values[256].

Level and Rate must Alternate: Any path through the structure of a system encounters alternating level and rate variables[257].

Level Completely Describes the Loop Condition: Only the value of the level variables are needed to fully describe the condition of a system. Rate variables are not needed because they can be computed from the levels[258].

Behaviour of Information Delays: Information result from at least one intermediate level affecting the subsequent rate in the feedback loop. Such delays cause an exponential smoothing of the levels in the feedback loop[259].

Behaviour of Physical Flow Delays: Physical flow delays result from at least one flow connecting two levels in a feedback loop. Such delays cause an exponential growth (or decay) of the levels in the feedback loop[260].

Information is not a Conservative Flow: Information is not depleted by use. It is not subject to conservation laws. Information can be transmitted to another point without destroying its existence at the source[261].

---

[253]*ibid.*, p. 5-8, Eqn. 5.3-2.

[254]*ibid.*, p. 9-3, Principle 9-2: Levels exist in conservative subsystems.

[255]*ibid.*, p. 4-9, Principle 4.3-5: Rates not instantaneously measurable.

[256]*ibid.*, p. 4-10, Principle 4.3-6: Rates depend only on levels and constants.

[257]*ibid.*, p. 4-10, Principle 4.3-7: Level variables and rate variables must alternate.

[258]*ibid.*, p. 4-12, Principle 4.3-8: Levels completely describe the system condition.

[259]*ibid.*, p. 8-19 to p. 8-24.

[260]*ibid.*, p. 8-25 to p. 8-28.

[261]*ibid.*, p. 9-4, Principle 9-4: Information not a conservative flow.

Behaviour of First order Feedback: The level in the first order feedback loop always exhibits an exponential time shape. For positive feedback, the positive exponential diverges from the equilibrium value. For negative feedback, the exponential always converges to the equilibrium[262]**.**

[262]*ibid*., p. 10-9, Principle 10.2-1: Exponential behaviour of first order loops.

Appendix 3

Principles of Systems

The following is an statement of the principles of systems[263] referred to as 'Syslogic' elsewhere in the treatise. It is meant to expose the premises of Syslogic and demonstrate the nature of conclusions that these premises make possible. Only a few important and illustrative conclusions (theorems) are stated here. Many more could be derived from the premises (structural domain). It becomes apparent from such a formulation that Syslogic is concerned with systems defined by actors and the nature, scope and dynamics of the acts of these actors.

Definitions

Stocks are accumulations of something. Stocks can be of kind (books, arms, people, etc.) or of the mind (frustration, love, anger, etc.). A relationship involves the partitioning of some stocks.

Events are happenings. A redistribution of a stock generates events.

Axioms

A system has a group of Actors[264].

Unless there are participating actors a system is impossible.

Actors in a system engage in a relationship.

Any interaction of actors is indeed a relationship.

Laws

Law of Action: *Actors use inscripts*[265] *to respond to events.*

---

[263]This should not be confused with Forrester's "Principles of Systems", which are in fact principles of feedback as can been seen from their statement in Appendix 2.

[264]✋An actor is anything that acts. Thus the thermostat which acts in response to the room temperature is as much an actor as a human. Throughout this treatise the word actor should be stripped of any "living" organism or human connotations.

[265]✋An inscript is a set of instructs☝ responding to an *class of events*☝. Inscripts are formulated as rules☝. An actor☝ lacks an inscript to an event☝ if the actor has no instructs☝ to respond to the event. An actor lacks an inscript to an event *class* if the actor has no rules to respond to that class of events.

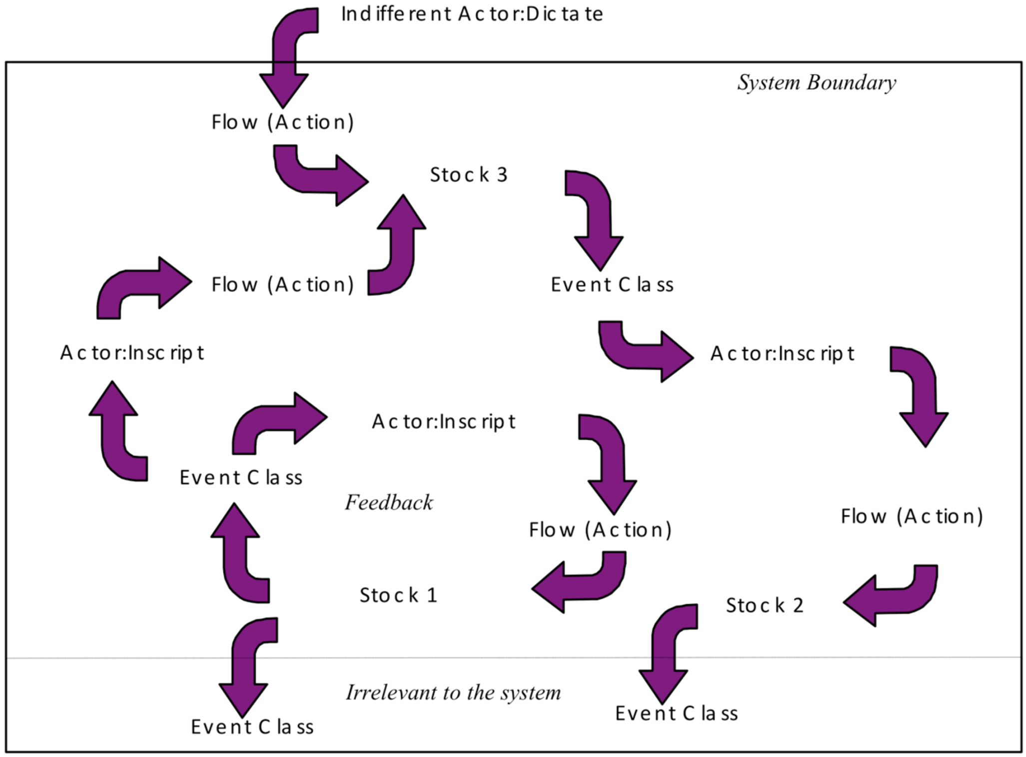

Figure 20 *A Simple system with an concerned and indifferent actor to illustrate the permutation of possible roles the concerned actor can have.*

Law of Vectoral[266] Action: *Inscripts of actors have a direction and strength.*

Law of Instructs[267]: *Each act is carried out through an instruct based upon a inscript.*

Law of the Act: *An act redistributes a stock.*

Theorems and Definitions

Indifferent actors: Indifferent actors are actors who influence a relationship with indifference. Thus indifferent actors do not respond to events generated by the state of the relationship in the system.

Potential of a system: The potential of a system is the set of event profiles that can be potentially generated by the system.

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[266] A vector has a direction and strength. In a system of human actors one would call vectoral action as purposeful action.

[267] An instruct is the actors act of responding to an event.

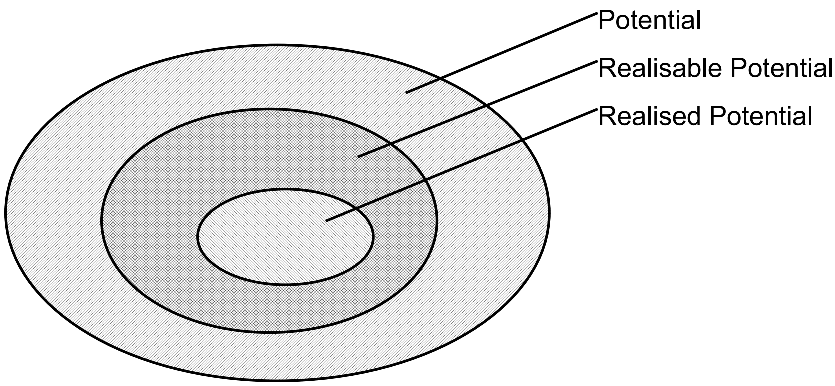

Figure 21 *Potential, realisable potential and realised potential in relation to each other.*

Realisable potential of a system: The realisable potential of a system is the set of event profiles that are realisable in practice, given the dictate of the indifferent actors.

Realised Potential of a system: The realised potential of a system is the event profile realised through particular decision on part of the concerned actors.

Surprise behaviour: A event profile is surprising if it does not follow the trend.

Feedback: An actor has feedback if the actor responds to events generated by the actor's acts.

Theorem 1: *Indifferent actors lack feedback.*

It follows from definition of indifferent actors that they do not respond to any event within the system. Feedback is impossible unless there is an event responded to. Therefore, indifferent actors lack feedback.

Corollary 1: *Concerned actors have at least one feedback.*
Corollary 2: *Concerned actors respond to events they attempt to change.*

Theorem 2: *Realities (or facts) are relative to the actor.*

Experience of reality is defined by the events in the event classes that the actor can recognise. Event classes recognised by different actors need not be the same. Even the events within the event classes need not be the same. Therefore realities can only be relative to the event classes and events that the actor can experience.

Theorem 3: *In order to maintain desired event profile an actor needs to respond to only those event classes that affect the desired event profile*[268].

[268]It is interesting to note that this idea is similar to Ashby's idea of *variety of the manager* needing to match the *variety of the system* in order that the systems variety be managed. The term variety is avoided here to prevent any confusion with Ashby's use of the idea. Those familiar with Ashby's concept, may notice the important implications of this formulation to Ashby's connotation. Contrary to Ashby's belief an actor *need not* respond to all the possible event variables in the system to have *requisite* variety. An actor needs to

Let us suppose the actor needs to maintain a event profile generated by a set of stocks (event classes) S_1. Let the system have S_2 stocks and let S_1 be less than S_2 (else $S_1=S_2$ which implies all stocks will need to be responded to). Then four possibilities exist: 1) all S_2 affect all S_1, 2) all S_2 affect some S_1, 3) some S_2 affect all S_1 or 4) some S_2 affect some S_1. In case of 1) and 2) the actor will need to be able to respond to changes in all S_2 to maintain S_1. In a better case the actor can identify a subset of S_2, by tracing any dependencies within S_2 so that only a smaller set S_3 needs to be responded to. In cases 3) and 4) the actor needs to respond to the S_2 which affect S_1 or in the best case can identify a subset *of the subset of S_2 that he need to respond to* by tracing dependencies within the S_2..

Theorem 4: *The potential of a system can be changed by changing the relationship alone*.

As the it is the relationship that dictates the acts in the system, it alone is responsible for the events generated in the system. Thus it is only the relationship that can change the potential of the system (Such a system with a new relationship is a *reactive isoform* of the original system).

Theorem 5: *Concerned actors can change the realisable potential of the system by new action inscripts.*

Since the realisable potential is the event profile restricted by the dictate of indifferent actors, and actors only use inscripts to respond to events, it follows that these inscripts alone can change the realisable potential (Such a system with new inscripts is a *response isoform* of the original system).

Corollary 1: *Decisions do not change the realisable potential.*
Corollary 2: *indifferent actors can change the realisable potential through their dictate.*

Theorem 6: *Concerned actors can change the realised potential of the system by new decisions.*

Since the realised potential is the event profile restricted by decisions of the concerned actors, they are influenced by decisions alone.

Theorem 7: *Surprise behaviour (if any) can be released by simulating different stock values.*

Since events correspond to stock redistribution, it follows that if some stocks are artificially redistributed, then actors can respond with decisions from inscripts that may normally never be used in combination. Thus they are likely to trigger stock rearrangements that are surprising. In other words, they generate surprise behaviour.

---

respond to *only* those events that affect the event variables important to the actor in order to have requisite variety.

Appendix 4

The Language NOW

NOW, Networked Object Worlds, is a computer language that allows to represent the models in Sylogic. NOW is similar to existing languages that allow the simulation of System Dynamics models. For now it provides the quickest framework to represent models in Sylogic. The *toolbox* contains a built in interpreter for the language NOW. It can, therefore, simulate the models and allow the exploration of the models written in NOW.

Names

NOW allows variable names, actor names and event names to be comprised of any combination of the following characters:

!"#$%&'().0123456789:;<>?ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghijklmn opqrstuvwxyz{|}~

As this includes the 'space' character, names can be typed as in natural language and it is not necessary to use the underscore character to separate words. Thus it is possible to name a variable as 'Predator Population' rather than an abbreviated form 'ppop'. Names cannot, however, begin with the space character. All spaces preceding the first non space character are skipped. Names may not contain arithmetic symbols, or the following characters:

+-*/=@,

NOW is case insensitive. Thus, the name 'Predator' and 'PREDAtor' are equivalent. Names can be of a length that pleases the user. All reserved words in NOW begin with the character '@'. Since this character may not be used in a name, names can not conflict with the reserved names.

Statements

Like earlier languages supporting System Dynamics, NOW uses a carriage return, as a statement delimiter. Thus a new statement is expected on every new line. NOW supports the following statement types:

Intermediate Computations	(A)	Descriptions	(D)
Stocks	(L)	Actor	(P)
Initial Stock Values	(N)	Events	(E)
Flows	(R)	Run Specs	(S)
Dictates	(C)	Copyright	(©)
Decision Values	(T)	Information	(I)

Each statement type is described by a statement character which is the first non space character on the line. Statements are written to comply with the theory of Syslogic. The syntax of each statement is thus legal if it does not violate the theory of Syslogic. The syntax and exceptions are described individually for each statement type.

Statement Types

Intermediate Computations

In the process of connecting the system one resorts to intermediate computations for the sake of simplicity. In NOW built-ins *cannot* be supplied with expressions as a parameter. One needs to therefore resort to intermediate computations. The Intermediates look like:

A ddp1=@max(0,ddp2)

A ddp2=dp-ddp

A ep=dp/dhr

The ‘A’ declares this as an intermediate computation.

Stocks

Stocks are also called levels in certain earlier languages to represent System Dynamics. To keep compatibility, NOW also uses the same convention. Given a stock, say population, its accumulation will depend on the time that has transpired since you last noted the system[269] and the rate of inflows or outflows in to the stock. Population increases as birth rates increase the inflow of people, and it decreases as the death rate increase the outflow of people. Thus:

L population=population+dt*(birth rate-death rate)

describes the statement in the form of an equation. In NOW it is necessary to add ‘L’ at the beginning of the equation to identify that the equation represents stocks.

Initial Stock Values

Typically one needs to specify the value of the stock when you inherit the system (initial value). In NOW you simply write:

N population=1000

This equation describes that we start off the system with a population of 1000 individuals. This statement must follow the declaration of the stock.

Flows

Flows are also expressed as rates. To keep compatibility with earlier representations in other languages, NOW also describes flows as rates. Thus, birth rates in the stock statement above could be population times the birth rate normal. In NOW we would state:

R birth rate=population*birth rate normal

Since the system already knows what population is we do not need to represent it again.

---

[269]Specified by the time step of integration or *dt*. See Run Specs later in this appendix for more details.

Dictates

Dictates of an indifferent actor are conditions imposed by an actor who is indifferent to the happenings in the system. The area available for a nature preserve, for example, could be the dictate of the city dwellers. Through their intentions or otherwise to encroach on the preserve for the purposes of agriculture, industry or leisure, the city dwellers dictate the amount of land available to the nature preserve. In a simple predator-prey system, the city-dweller becomes an indifferent actor, his decisions being independent of the happening in our system. In NOW we represent this dictate as:

C area=1e5,1e2,1e7,City Dweller

the 'C' declares the dictate (which remains a constant during the run unless changed during the run by the user to examine the behaviour of the system under new dictates). The three numeric values specify: the current value, the minimum value possible, the maximum value possible. The "city dweller" at the end of the statement declares that it is the city dweller who is the actor who dictates what value is actually existing in the system.

Decisions

Decisions are reached through a rule by an concerned actor. Rules are applied conditionally. They have the standard form: *if a certain event then a particular response/decision*.

The forest authority, for example, may decide to reduce the predator population every 20 years beginning 1880. If it is 1880 they let the population be 266, if the year is 1900 then the population is still 266, if the population is 1920 the population is reduced to 0, if the year is 1940 the population is reduced to zero and if the year is 1960 the population is reduced to 0. If the year is one unspecified, extrapolate between the previous specified value and the next specified value. Thus for years between 1900 and 1920 the predator population will be extrapolated between 266 and 0.

Such a rule is stated in NOW as follows:

A predator population=@tabhl(pp rule,time,1880,1960,20)

T pp rule=266,266,0,0,0,Forest Authority

The 'A' specifies that this is an intermediate computation. The '@tabhl' is a built-in function[270] that allows to represent rules that need extrapolation. It reads:

if time is less than or equal to 1880, apply first value from the table 'pp rule'. If the time is greater than or equal to 1960 then apply the last value from the table 'pp rule'. If the time is in between, values are specified at intervals of 20 in the table 'pp rule'. Extrapolate when necessary.

The 'T' specifies the table as required by the statement of '@tabhl'. In this case five values of predator population as desired in 1880, 1900, 1920, 1940 and 1960 are specified. The final field indicates which actor applies this rule for decision making. In this case the forest authority.

The 'T' statement must follow the decision statement in which the '@tabhl' is declared.

There are often cases when rules do not extrapolate between bounds as above. Using the '@rule' built-in function in place of '@tabhl' works identically but does not extrapolate between bounds. It

[270]See also the list of built in functions later in this appendix.

applies the prevalent rule till the prevalent rule changes. Thus substituting '@rule' in the above equation will result in population remaining 266 till 1920 and dropping to 0 in 1920.

Every event in the decision statement must be backed by an event statement (described later in this appendix). It is not good practice to specify a decision whose events are not described in event statements.

Descriptions

Any stock, flow, dictate or decision can be described using the 'D' statement. This allows the user to get a better understanding of the stock, flow, dictate or decision described. It is good practice to use the 'D' statement to describe a stocks role for the actors, the rates meaning and units, the dictates meaning (and reason if known) and the purpose of the rule for the decisions.

T nirt=-.5,-.15,0,.15,.2,Deer

D nirt=Deer Increase Rate fraction

Commas (',') may not be used within descriptions.

Actors

As we saw in representing rules and decisions in the language NOW, we specify who decides. Additionally, you may describe the actor after you have declared his action in a decision statement. Thus, one can describe an actor after a decision statement as:

A nir=@tabhl(nirt,fpd,0,2000,500)

T nirt=-.5,-.15,0,.15,.2,Deer

D nirt=Deer Increase Rate fraction

P Deer=The Primary Consumers, the Prey.

The 'P' indicates one is describing the player (or actor). The name of the actor as used throughout the system representation follows. A short description of the actor follows. This statement helps describe the role of the actor in the system for a user who is exploring the system for the first time.

The 'D' statement allows to describe any variable in the system after its declaration. The name of the variable is followed by the description.

Commas (',') may not be used within descriptions.

Events

Events are caused if the value of a variable lies between a range. In NOW one simply describes an event as:

E Deer Extinction=dp,0,1,Deer have been made Extinct

E Deer endangered=dp,100,800,Warning!!! Deer may get Extinct

E Famine=food,0,50e6,Severe food shortages in the Ecosystem

The 'E' indicates that this is an event statement. The name of the event is described next. The event variable (the variable whose values cause the event) follow. The numbers which follow are the range of the event variable that corresponds to the event. The statement ends with an event description.

The same variable may describe hundreds of events. Typically every event in the decision statement should also be described by an event statement. Events which are not part of the decision repertoire may be specified only to illustrate that the "indifferent" observer can see events that are unimportant to the actors in the system.

Commas (',') may not be used within descriptions.

Run Specs

Run specs indicate the virtual start time, virtual end time, the virtual step time for integration at the virtual print interval during the simulation of the model. To indicate run specs simply type the 'S' statement in NOW:

S 1880,1960,.25,1

The first number indicates the virtual start time for simulation, the second number the virtual end time for simulation. The third number indicates the virtual step time and the fourth number the virtual print interval time for simulation.

Information

Each model can have one information statement. This statement indicates the name of the model and contains a short description of the system being modelled.

i predator prey model=This is a model of the predator prey relationships

The '=' sign demarcates the name from the description. Commas (',') may not be used within descriptions.

Copyright

Each model can have one copyright statement. The modeller can indicate the name of the developers, year and version number in such a statement.

© (1976) Original Development Donella Meadows Michael Goodman (1992) adaptation by Anupam Saraph

Commas (',') may not be used within statement.

Built-In Functions

NOW supports several built-in functions. Some functions are provided for compatibility with earlier languages supporting System Dynamics, like dynamo and stella. Here is a quick summary:

Functions for decisions

@TABHL(p1,p2,p3,p4,p5): Tabhl allows you to describe a rule. p1 indicates a table variable, p2 the event variable, p3 the low value of the event variable, p4 the high value of the event variable and p5 the step interval of the event variable for which decision values are given in table described by p1.

@CLIP(p1,p2,p3,p4): Clip is the binary form of table. If p3 is >=p4 then the decision is p2 else p1.

@SWITCH(p1,p2): Switch outputs yes or no (1 or 0) depending on whether p1>p2. Both clip and switch are provided for compatibility only. They shall be replaced by the 'rule' function in newer versions of NOW.

Functions for input

@SMTH1 or @SMOOTH(p1,p2,p3): These correspond to the first order smoothing. p1 is input to be smoothed, p2 is averaging time, p3 is the initial value to return.

@SMTH3 or @DLINF3(p1,p2,p3,p4,p5): These correspond to third order smoothing. p1 is input to be smoothed, p2 is averaging time, p3 is the initial value to return. p4 and p5 are dummy variables.

@STEP(p1, p2): This function gives a step of p1 at time p2.

@PULSE(p1,p2,p3): This function gives a pulse of p1 beginning time p2 and every p3 interval.

@MIN(p1,p2): Min returns the minimum of p1 and p2.

@MAX(p1,p2): Max returns the maximum of p1 and p2.

Functions for output

@SOUND(p1): Produces a sound if p1 is non zero.

Functions providing system information

@TIME(): Returns the current virtual time during the simulation.

@DT(): Returns the virtual step time for simulation.

@STARTTIME(): Returns the virtual time the simulation started.

@ENDTIME(): Returns the virtual end time during the simulation.

@PRINTINTERVAL(): Returns the virtual interval for capturing and storing values of variables

Functions for mathematical operations

@INT(p1): Returns the largest integer less than or equal to p1. @int(8.9) is 8

@ROUND(p1): Rounds p1 to the nearest whole number. @round(3.4) is 3 and @round(3.5) is 4.

@EXP(p1): Returns e to the power of p1.

@LOGN(p1): Returns the natural logarithm of p1.

@LOG10(p1): Returns the logarithm to the base 10 of p1.

Example

The following is a listing of a simple model adapted in NOW. This model as all models use the insights of the analysts (scientists) studying the specific set of actors being modelled to understand the reactivities and inscripts of these actors. The mathematical statements of the relationships are then translated into the computer language to enable the computer to interpret the mathematical relationship.

```
i predator prey model=This is a predator prey model to illustrate dynamics of predator prey relationships
© (1976) Original Development Donella Meadows Michael Goodman (1992) adaptation by Anupam Saraph
l dp=dp+dt*(dni-dpr-dhr)
n dp=4000
d dp=Population of the Deer in the Ecosystem
r dni=dp*nir
d dni=Net Increase Rate of Deers
a nir=@tabhl(nirt,fpd,0,2000,500)
t nirt=-.5,-.15,0,.15,.2,Deer
d nirt=Deer Increase Rate fraction
p Deer=The Primary Consumers. Any Prey in a Predator Prey System.
a fpd=food/dp
r dpr=pp*dkpp
d dpr=Predation Rate
a dkpp=@tabhl(dkppt,dd,0,0.025,0.005)
t dkppt=0,3,13,32,51,56,Predator
d dkppt=Deers Killed per Predator
a dd=dp/area
d dd=Deers per Unit of Area
c area=800000,0,1e5,City Dwellers
d area=The Ecosystem that is the Scene of the Play
a pp=@tabhl(ppt,time,1880,1960,20)
d pp=Population of Predators
a time=@Time()
t ppt=266,266,0,0,0,Forest Authority
d ppt=Predators Allowed to Remain in the Ecosystem
l food=food+dt*(frr-fcr)
n food=470e6
d food=The Vegetation in the Ecosystem: Primary Producers
r frr=(foodm-food)/frt
d frr=Vegetation Regeneration Rate
c foodm=480e6,0,480e6,Nature
d foodm=Carrying Capacity of the Land for Primary Production
a frt=@tabhl(frtt,dpf,0,1,0.25)
t frtt=35,15,5,1.5,1,Nature
d frtt=Time for Vegetation to Regenerate
a dpf=food/foodm
r fcr=@min(food,dfc1)
d fcr=Vegetation Consumption Rate
a dfc1=dp*mfcpd
c mfcpd=2000,0,2000,Deer
d mfcpd=Max Vegetation consumed per deer per day
r dhr=@clip(ddp1,0,time,dht)
```

d dhr=Rate at which Deer are removed by Humans from the Ecosystem
a ddp1=@max(0,ddp2)
a ddp2=dp-ddp
a ep=dp/dhr
c ddp=0,0,1e8,Environmentalists
d ddp=Desired Deer Population
c dht=2000,1880,1960,Forest Authority
d dht=Year from which Deer will be removed from the Ecosystem to reduce them to desired level
s 1880,1960,.25,1
e Deer Extinction=dp,0,1,Deers have been made Extinct
e Crowding=dd,1,.5,Severe Crowding of Deers in the Ecosystem
e Famine=food,0,50e6,Severe food shortages in the Ecosystem
e Deer endangered=dp,100,800,Warning!!! Deer may get Extinct
e Excessive Poaching=ep,.5,.2,Too many Deers being Killed
e Predators Removed=time,1920,1921,Predators removed from the Ecosystem
e OverGrazing=dpf,.8,0,Too much vegetaion being eaten by Deer.
e Over Predation=dd,.010,.025,Excessive Deer being Lost

Appendix 5

The Visible Toolbox

A typical interaction with the *visible toolbox* requires the user to load a tool[271]. The “Tool Open” menu (Figure 22) opens the “File Open” dialogue box (Figure 23). Using this dialogue box it is

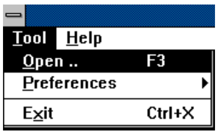

Figure 22 *The tool menu allows to open the file open dialogue box.*

possible to choose the filename which contains the tool to be loaded. If necessary the a different drive or directory can be chosen. Different tool categories can also be selected by choosing an alternate file type to list. When a file is selected by clicking the “OK” button, the tool loads in to the toolbox.

The information from a model is displayed as *lists* of actors in the system being modelled, the decisions of these actors, the flows these decisions affect and finally the stocks that are involved in the relationship. Figure 24 illustrates the result of loading the predator-prey model listed in appendix 4. The “actor menu” (Figure 24), activated by shift key + right mouse button when the actor list

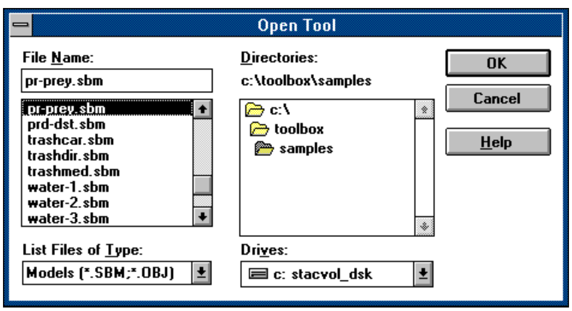

Figure 23 *The file open dialogue allows to open a tool.*

[271]Tools can be either models defined in Syslogic (using the language NOW), or databases of past performance of some system or literature (case studies of some system).

box is in focus[272], allows to toggle the display of external actors in the system. For example the external actors in the predator-prey model (as defined in the model in appendix 4) are environmentalists, city dwellers etc.

The "decision menu" (Figure 25), activated by shift key + right mouse button when the decision list box is in focus, allows the possibilities to overrule the inscript decisions for *one* iteration[273]. It is

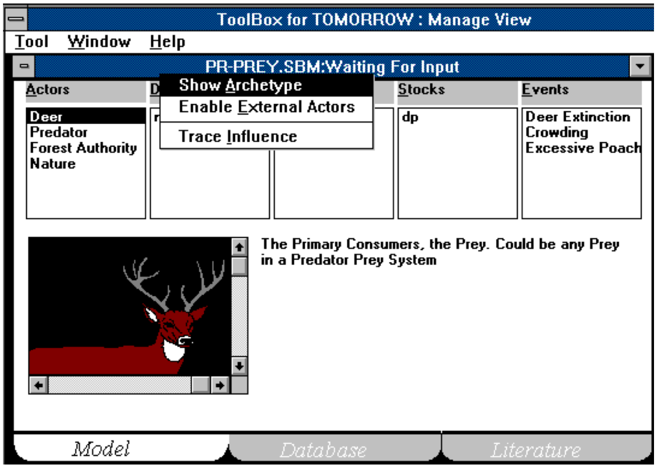

Figure 24 *A model in the visible toolbox*

also possible to toggle adding to the list of decisions the dictates (external decisions) using this menu. Thus it is possible to change a *dictate* during a simulation to explore what different potential was

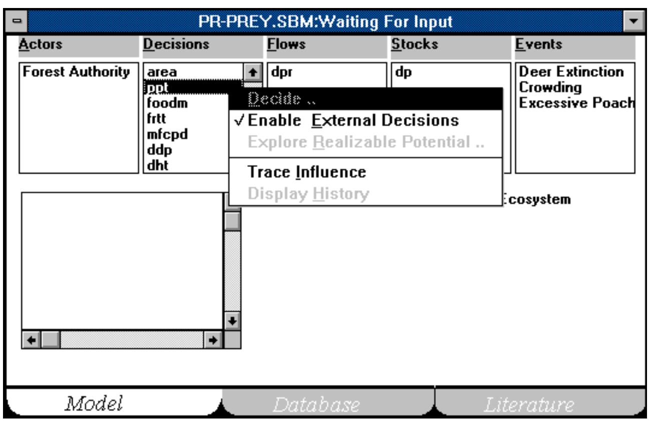

Figure 25 *The decision menu in the visible toolbox.*

[272]A list box is in focus if any item in it is selected (displayed in inverse video).

[273]This menu is activated (not greyed) only if the toolbox is in the management mode *and* the model is running.

realised by the alteration of the realisable potential. It is also possible to explore changes in decisions by responding to events as they occur and intervening in the system in *real time*.

The "event menu" (Figure 26), activated by shift key + right mouse button when the event list box is in focus, allows to switch to the literature mode when the model is running to watch a "story" unfold. The time horizon of a model (the period over which the model is simulated) can be changed through this menu. Thus it is possible to "run" a model for ten years and then continue further by another ten years. Each event is recognised at a certain sensitivity. Altering observation sensitivity is identical to reassigning the events in an event class. This can be used to explore the consequence of alternate information channels or systems to generate or avoid certain event profiles.

It is possible to trace influence of every actor, decision, act, relationship or event through the

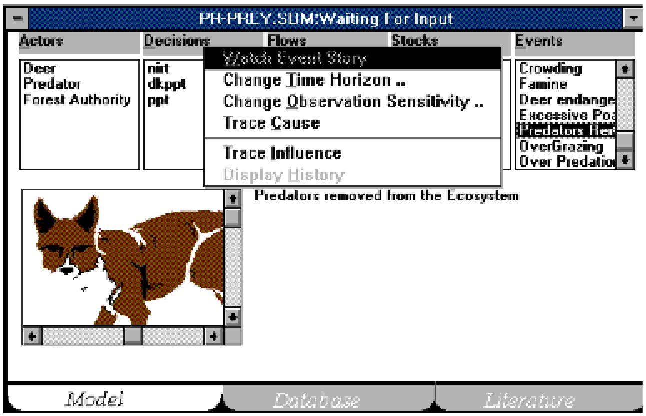

Figure 26 *The event menu in the visible toolbox.*

appropriate menus. Once a model is simulated, it is possible to explore the "history" of the selected decision, flow, stock or event through the appropriate menu.

Switching between the *modes of interaction* toggles certain relevant menus. The research, communication and management modes can be toggled through the mode menu (Figure 27), obtained by pressing the right mouse button.

Model simulation is controlled through the "simulation menu" (Figure 28), activated by ctrl key + right mouse button when any list box is in focus. Once the model is being simulated, it is possible to switch to the literature or database view to display the story as it unfolds or capture and analyse the history.

Figure 27 *Switching purposes in the visible toolbox.*

In the database menu (Figure 29), activated by shift key + right mouse button when the database is under view, it is possible to select the variables to list in the spreadsheet and plot on the graph. The table (spreadsheet) and graph views can be altered through this menu. Figure 29 displays the deer population after the simulation of the predator prey model.

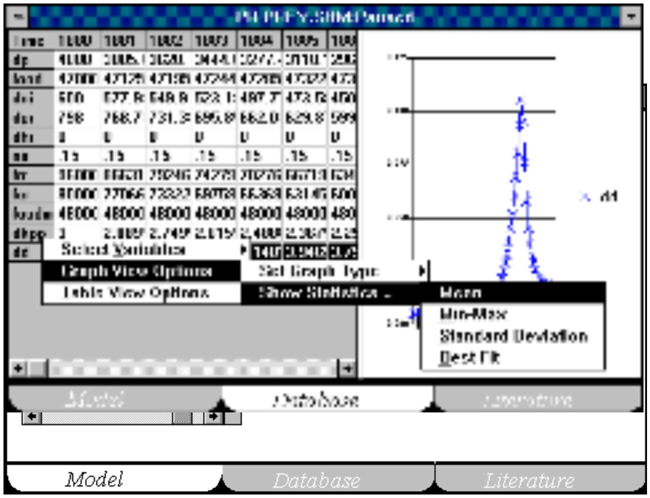

Figure 28 *Simulating a model in the visible toolbox.*

The database view option (Figure 30), activated by right mouse button when the database is the active view allows to display table only, graph only or both. It allows to change display options for the graph and table grids, depending on which is active. Different event variables can be displayed on the same graph by selecting them in the table (using shift and cursor keys) and then “turned” to graph through this menu.

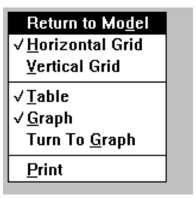

Figure 30 *Options for viewing the database.*

In the literature mode it is possible to watch a story unfold. The story can be viewed from the beginning, replayed, or viewed at different speeds through the “literature menu” (Figure 31), activated by shift key + right mouse button when the literature view is the active view.

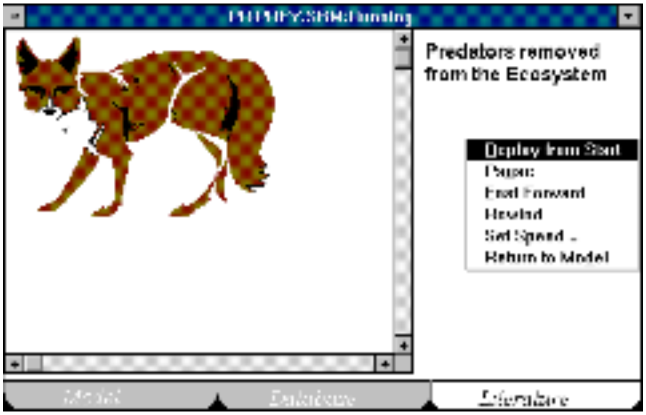

Figure 31 *Watching events in the visible toolbox.*

Appendix 6

General Theory of Organisation of Systems

The following is a statement of the theory of organisation of systems. It is meant to expose the premises of the theory and demonstrate the nature of conclusions that these premises make possible. Only a few important and illustrative conclusions (theorems) are stated here. Many more could be derived from the premises (structural domain). It becomes apparent from such a formulation that the theory is concerned with the nature and dynamics of existence. As a consequence the theory is universal to all existents, known and unknown and serves as a universal fundamental theory. It can become apparent to the reader on some reflection that the propositions of the theories described in Appendix 1, 2, and 3 can be derived from the premises of this theory. At the same time the fundamental nature of these premises widens the scope of the functional domain enormously.

Axioms

There is.
It is evident that there is. Existence of something is prerequisite and axiomatic for the operation of what follows. Existence of something is evident *irrespective* of the metaphysical beliefs of the observer. For unless there exists something, there would be no observation, question or act.

Acts[274] *are a response to some event.*
If acts were not a response to some event then there would be no reason to forecast, anticipate and observe any order.

Laws of Organisation

The law of nature of identity: *All existents are actors*[275].

The law of role: *Actors act.*

The law of characterisation: *All acts modify some attribute of some actor.*

The law of conservation: *Existents can not be created or destroyed, only acted on.*

---

[274] Acts are themselves recognised by an observer as events. For the observer they are thus the events generated by an actor.

[275] An actor is anything that acts. Thus the thermostat which acts in response to the room temperature is as much an actor as a human. Throughout this treatise the word actor should be stripped of any "living" organism or human connotations.

Like the fundamental laws of thought[276], upon which the theory of logic is based, these laws may seem absurdly obvious. By the very reason that fundamental propositions are irreducible to simpler propositions, fundamental propositions will be absurdly obvious. It is the theorems or secondary propositions that follow from the axiomatic framework subjected to these laws that will indicate the value of the theoretical framework of organisation.

Definitions

Events: Events are happenings in the eyes of the observer[277]. They are themselves *actors with particular characteristic* which became apparent to the observer. Acts are often considered events in common language. This is reminiscent of the recursive nature of the universe and makes sense only if one were investigating acts as events and not as acts.

Reactivity: Reactivity is the actors ability to recognise and respond to an event. Actors can recognise the same events but respond differently. Actors can also react identically to different events. When actors recognise the same event and respond identically then they can be said to have the same reactivity.

Role: Role of an actor refers to the ability of that actor to recognise *and* participate in the system.

Theorems

Theorem 1: *A world without actors is impossible.*

Let us imagine a world devoid of all actors. In such a world every change and the resultant organisation is attributed to a "demon" which can note every state and respond with an appropriate new state. It is then obvious that such a "demon" would be an actor itself!
Corollary 1: *No organisation is possible without an actor.*
Corollary 2: *The simplest unit of organisation (orgatom) is an actor.*
Corollary 3: *Actors without reactivity are impossible.*
Corollary 4: *Actors exist irrespective of any metaphysics adapted by the observer.*

As examples of actors one can note that the thermostat which recognises changes in temperature and responds to it is as much an actor as is the predator who responds to the prey in recognition of its hunger. So is the carbon atom which responds to the neighbouring oxygen through a sharing or transfer of electrons and *vice versa*.

---

[276]The propositions "whatever exists exists, things can not exist and not exist at the same time and everything must exist or not exist" have been referred to as the "laws of thought". The mathematical theories of logic and probabilities were based upon these "fundamental" propositions by Boole (See Boole, G., *An Investigation of the Laws of Thought: On Which are Founded the Mathematical Theories of Logic and Probabilities*, Dover Publications, New York, 1854, p. 39-51 where Boole derives these propositions as the laws of thought). These propositions are also called the law of identity, the law of contradiction and the law of the excluded middle.

[277] An event is a happening that falls out of the "normal" pattern of the observer. An event is thus something relative to the observer. Events evoke a response of some kind. Thus while sun rising is an "event" to somebody watching the darkness of the night, it is not an "event" to somebody who is in a windowless room when the sun rises. An event is necessarily a "process" that lasts over a duration. It can be recognised only when it lasts at least as long as the duration that the observer samples for its occurrence.

Theorem 2: *When actors act, they accumulate some actor in partitions on the basis of some characteristic that the actor partitioned possesses.*

From the law of conservation of existents it follows that actors can only be acted on. It therefore follows from the law of characterisation that acts 'move' the actor acted on from a partition of one characteristic to another. Thus each partition is subject to accumulation of actors possessing characteristic that distinguishes the partition.

It follows that if p1 were the characteristic of actor A which were modified to p2 by actor B at a rate determined by some rate $R_{p1\text{-}p2}$ then we can estimate the quantity of actors in partition A_{p1} and A_{p2} by simple integration as:

$$Ap1 = \int (- Rp1\text{-}p2)dt$$

$$Ap2 = \int (Rp1\text{-}p2\ )dt$$

For example: the oxygen atom engages in exchange of electrons with the carbon atom if its outer electron ring has insufficient electrons. In the exchange process the electrons are partitioned differently than before. A hungry predator eats the prey. In the process the prey population accumulates between the alive and the preyed.

Theorem 3: *Reactivity defines and dictates what the actor can respond to.*

From the definition of reactivity as the ability of the actor to recognise and respond to an event, it follows that if the actor lacks reactivity to an event the actor cannot respond to it. Conversely, it is what the actor can respond to that dictates what the actor can respond to.

Theorem 4: *On encounter, actors with reactivities to a common actor organise around a relationship to constitute a system.*

From theorem 3 it follows that reactivity dictates what actors respond to. If two or more actors with reactivity to a common actor encounter each other, they would respond to different characteristics of the same actor. Their interaction in this relationship *defines* a system.

It is thus possible to represent system S as comprising of actor A_1 to actor A_i with reactivities s_1 to s_j such that for all A_i there is at least one s_j is capable of recognising a characteristic of another actor. Figure 32 describes the concept visually. Actors A_1,A_2 and A_3 constitute a system S_1 because at least one s_i is capable of recognising a characteristic of another actor. S_1, S_2 and S_3 are different systems because their actors organise around different reactivities incapable of recognising a characteristic of the actors within[278]. Actor A6 may have reactivity recognising a characteristic within itself, thus defining system S3.

Examples of relationships that define a system include: the predator by responding to the prey engage in a relationship with the prey. The oxygen atom by responding to free electrons of carbon engage in a relationship with the carbon atom and the electrons. The thermostat by recognising entropy content of the air engages in a relationship with its entropy content.
Corollary 1: *The purposes of a system is a consequence of the reactivities of its participating actors.*

[278]It may be noted here that the actors in S_1 will be unable to recognise or participate in S_2 or S_3. This will be true in the converse too. The actors from one system thus lack *role* to participate in another system.

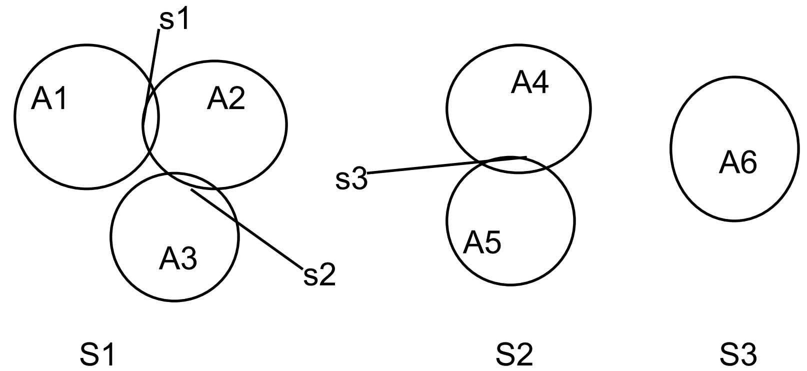

***Figure** 32 Actors A1-A6 organised in to systems S1-S3 based on their reactivities s1-s3.*

Theorem 5: *Systems associate (expand) to accommodate combined reactivities of its actors.*

From theorem 3 it follows that reactivity dictates what actors may respond to. Thus if actors have reactivity that is not satisfied in the system S, then when conditions arise that the reactivity can be satisfied, it follows from theorem 3 and theorem 4 that the system is redefined to S' to accommodate the reactivity of the actor.
Corollary 1: *New reactivity and/or new encounters make reorganisation possible.*

Examples of such expansion include: the carbon and oxygen engaged in a relationship may soon find another oxygen entering the redefined system (S'). The earlier relationship between the carbon, oxygen and their electrons failed to satisfy the complete reactivity of the actors participating in the relationship. The seller engaged in a relationship of transfer of goods to the buyer may engage in selling to other buyers or selling other goods. The redefined system(S') is thus not more of the same relationship but qualitatively different from its predecessor system(S).

Thus in the illustration from **Figure 32**, if actor A_1 had reactivity s_3 then system S_1 would expand to S_1' or S_2 would expand to S_2'. The stability of S_1 or S_2 in their native states will depend on the possibility of encounter of S_1 with S_2.

Theorem 6: *Systems disassociate (contract) to simpler systems when the one or more actors can no longer service one or more of their reactivities.*

From theorem 4 we recognise that the system is organised together through reactivities. If for some reason actors can no longer service or keep the reactivity that held together a relationship, it follows that the system is now redefined into smaller systems on the basis of the new actors participating in a relationship.

In the illustration from **Figure 32** system S_1 breaks up into system S_a and S_b if reactivity s_1 cannot be serviced[279].

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[279]This can be termed as a *saturation* point of role for the actor who fails to service the reactivity.

For example, under a changed dictate of high energy (for example through electrodes) the reactivity of hydrogen to oxygen to form the system water can not be serviced. Thus water disassociates into simpler systems of hydrogen and oxygen. Under feeding predators artificially (external dictate) the predator prey relationship breaks up.

Theorem 7: *A system is closed to reorganisation if for every characteristic of every actor there is at least one actor within the system with a reactivity to it .*

If for every actor every characteristic distinguishing the actor is acted upon by some actor within, then there can be no possibility of system expansion unless new reactivities to characteristic of actors outside the system develop. This follows from noting theorem 4 and noting that what characteristics there are, are saturated in this system.
Corollary 1: *A system is open to reorganisation if no actor within the system has reactivity to any characteristic of at least one actor*[280].

Theorem 8: *Acts of actors to respond to events dictate rates of partition sorting some actors.*

Theorem 2 noted that action accumulates some actors in partitions. From the law of role (that actors act) and the axiom that acts are a response to some event it follows that actors act to respond to events. It is thus the acts that specify the act of partitioning when the event takes place. They are thus rate statements when viewed over a continuum of time.
Corollary 1: *Actors influence a system by their (non)reaction.*

Theorem 9: *Actors get feedback of their action if for the event in response to which they modified a characteristic of an actor, there exists some actor who can sense the original or modified characteristic, and who, through similar recursion or directly, can modify the event.*

From the fact that a link can be trace from the event to event through whatever intermediates, there exists a feedback.
Corollary 1: *All theories of feedback dynamics apply to such actions*[281].

Theorem 10: *A system is sustained if the relationships within the system can be sustained.*

From theorem 4 we define a system. It follows from theorem 6 that a breakdown of a relationship breaks the system. Thus if the relationship can not be sustained, the system can not be sustained.

Theorem 11: *Observers can observe events irrelevant to a system*.

An observer of an system can observe only events that are within the reactivity of the observer. Unless the observer is a part of the system, the observer can observe events which occur in the system but no actor within the system has a reactivity to them. For example observing exponential decay of pieces on the board in chess, the observer observes events irrelevant to the system of chess. Thus unless the observer is part of the system, the observer can observe events which occur in the system but are of no consequence to the system.

[280]An actor satisfying this criteria will be referred to as an *external* actor throughout the treatise.

[281]For example Forrester's principles of systems, which is really the theory of feedback dynamics (See Appendix 1), can apply to such systems.

Summary

The exercise to construct a toolbox for operating on change and sustainability was undertaken out of the concerns voiced over the last two decades about the rapidly reorganising world which seems to move away from promising to sustain the human race (and much else). The pressures on sustaining environmental quality and environmental health form a major concern in the west and north, while a concern for survival form's a major concern in the east and south. At institutional levels and even individual levels there is an ever increasing effort to comprehend and manage change to sustain the level. While civilisations of the past have used several tools, they have not succeeded in sustaining themselves. This treatise is therefore motivated to explore and design the tools that can enable operate on the domain of *change* and therefore of *sustainability*.

In an exercise to construct a toolbox containing tools operating on the domain of change and sustainability, it is first necessary to examine the nature of the tools that are commonly resorted to in order to address the question of change and sustainability. How can indeed such tools be compared? What are the benchmarks which allow us to evaluate a tool? It is these questions that can give us insights into designing new tools. Every concept is a tool. Tools are characterised (or can be described) by their *structural* domain. The real world on which the tool can operate (the *functional* domain) is restricted by its structural domain. Tools can therefore be evaluated for their *adequacy* to operate on a functional domain of *choice*. They can also be evaluated for themselves being based on other tools (which can come to be questioned) or for restricting the scope of the tool by containing *secondary* propositions in their structural domains. Tools can allow the users to "observe" only within the scope of the *mapping* of the structural domain onto the functional domain. Thus while opening up the possibilities for observation, they restrict the users to the domain addressed by the tool.

Change is the only constant thing in the universe. Observers can observe change in the form of events with the aid of the "tools" they are equipped with. Civilisations strive to *sustain* a desired order. Order itself is changing. The question of sustainability is therefore the question of change management. The typical tools to address the order (and manage change) are the tools of *problem solving*, *knowledge systems* and *systems*.

The tools of problem solving are equipped to look at *problems*. Problems are *relative* to an observer, with a set of tools and in a particular setting. If any of these changes, as they inevitably have to, problems may no longer be problems. At best solving problems is *displacing* them to another system or into the future. The result is inevitably a *problem-solution* spiral. Such tools are therefore *inadequate* to address the question of *change management* or *sustainability*.

The tools of knowledge systems are equipped to collect in great detail "knowledge" and "information" about highly specialised subjects. Since one person can not possibly store, access and use (asses) such knowledge, collective "knowledge accumulators" are found (or *coding* in the form of specialists, computer data banks etc.). This tool (strategy) of overcoming the inherent limitations of any individual (or device) to accumulate knowledge by coding, ironically leads to *recursive amplification* by mappings being based on other mappings. Additionally such mappings are not free of problem solving tools themselves. There is no guarantee of *relevance* in using recall for knowledge or information in such systems. It is obvious then that such tools can be *inadequate by virtue of irrelevance* to address the *management of change* and *sustainability*.

The tools for systems identify *functional units* of reality. They thus operate on elements which are of direct functional significance. The tools however do not specify a means to *identify* a functional unit and leave such definition to the analyst. There is thus little possibility to *share* an understanding, or even express its *scope*. Some tools of systems are themselves based on other tools or have secondary propositions in their structural domain. They therefore not only restrict the scope of their operation but also rely on the correctness of the tools they are based on. It is therefore that these tools (in their present form) are likely to be *inadequate* to address the *management of change* and *sustainability*.

For reasons of the inadequacy of the existing tools, some of which are described in part one, new tools were designed to address the domain of *change* and therefore of *sustainability*. The toolbox contains these new tools: Syslogic (or the logic of systems) and the general theory of organisation of systems. Syslogic is a tool which specifically allows to identify systems in a fashion that their identification can be *shared*. It also allows to explore the potentials of such systems once they are identified. It can thus be possible to trace whether desired potentials lie within the realisable potential or even the potential of a system.

Syslogic identifies systems as comprising of *actors*. If a list of actors engaged in some relationship can be specified, a system is defined. Each change in relationship of the same actors represents a *reactivity-isoformic* system. Each actor responds to events through *inscripts*. Identical systems with actors having different inscripts are *response-isoformic*. Having identified a system with Syslogic, different *isoforms* that are felt to be prevalent can be investigated. Syslogic provides a means to identify the influence of *internal* and *external* actors on realising the *potential* of the system. It presents reality *as experienced by each participating actor*. Using Syslogic pictorial models of systems can be constructed. These models can then be transferred to a mathematical form using the computer language, NOW (designed specially for models in Syslogic), that makes the mathematics transparent to a large extent. A software, *the visible toolbox*, has been designed, with an interpreter for the language NOW, to enable explore simulations of models in Syslogic. It can serve as a research laboratory, teaching tool, communication aid and managers support system.

Since systems are themselves in constant change and Syslogic cannot account for changing systems it became necessary to develop the general theory of organisation of systems. The general theory of organisation of systems originates in the need to seek *building blocks* of all organisation *irrespective* of the physical composition (nature). The theory is built on the nature of all existents. The laws of organisation attribute an identity, role, characteristic and conservation to every existent. Each existent being an actor, events become actors themselves. The *reactivity* of each actor dictates and restricts the nature of organisation (or reorganisation) that can take place when a group of actors interact with each other. The *orgatom* (simplest unit of organisation) is the existent (actor). It becomes clear that organisation itself cannot be created or destroyed but only reorganised. A *system* then is *defined* by the interacting actors and by their reactivities. We have then a *building block* basis for all organising systems. The theory can therefore be used for *design* of organisation in a synthetic manner rather than only as an analytic tool to understand systems.

The general theory of organisation of systems is a tool which allows to explore the *life cycles* of organisation of a system. It provides a building block for all organisation, *irrespective* of the physical nature of the organising substance. Such building blocks can then be used for both analysis as well as design. Like bricks or atoms, building blocks are tools that offer a variety of complex structures to be built. It is outside the scope of this treatise to encompass all of these.

The tools leave the burden of use on to the user of the tool. These tools can be applied to *all* systems and organisations, known or unknown, irrespective of their physical characteristic. The tools can be applied for understanding, communicating or even managing the organisations and/or systems they operate on. That is precisely why the consequences for operating on the world for purposes of understanding, communication and management are presented.

The general theory of organisation of systems points out that the observer (or analyst) needs to have reactivity to what is observed. The important consequences of this requirement are that at worst irrelevant observations could be highlighted and at best one can learn about the potential of a system if the observation does not alter the isoform being "observed" into another isoform. The possibility to use this tool *synthetically* makes it possible to construct organisations and explore their stability as well as possibility of existence. *Self-Awareness* as identified by the theory is the reactivity to ones reactivities. *Learning* is the ability to add reactivities. Environmental issues arise as a consequence of organisation of systems. It is therefore doubtless that the first step in managing the environment needs to understand organisation. *Environment* in the theory is the *system*. It thus brings questions to manageable sizes. The theory points out the contrast between *sustaining* a system and *evolution*.

With Syslogic it is possible to distinguish three levels of management: the management of *states*, the management of *change* and the management of *relationships*. The event-driven state manager can explore the alternatives for state management using the tool of Syslogic. The change manager can explore different *response isoforms* in realising the potentials of his system. The relationship manager can explore different *reactive isoforms*. With the theory of organisation of systems it is possible to distinguish yet another level of management: the management of *organisation*. Organisation managers explore the possibility of different systems in a constantly reorganising world.

The tools of the toolbox complement the tools of traditional science by allowing the exploration of the consequences of systems with inscripts of objects understood by traditional sciences. While some complementarity is illustrated the application of these tools to important systems like personal organisation for individuals to large scale multinational bushiness is left for future research.

While creating important possibilities for understanding, communication and management of the universe, especially "environmental questions", the tools also have important implications for design of automata and "artificial or machine intelligence". Four of the six appendices summarise the technical aspects of the tools and the toolbox. The other two appendices present a structured reformulation of two common systems tools to facilitate comparison and illustrate their scope.

These tools, like all tools, do not expect to be exempt from the laws of change. What is presented here is the first version, and does not claim to be "final" in any form at any time. Like everything else, tools will also organise themselves to newer versions or newer tools through time.

In conclusion the *toolbox* is literally a toolbox for *tomorrow*. Organisations define tomorrow. If tomorrow were to be possible for human systems, we need to understand organisations and the principles of organisation. Here are the building blocks for *all* organisations. They are presented with the hope to help organise functionally relevant and humane organisations for generations to come.

Samenvatting

Het construeren van een gereedschapskist (“toolbox”) voor het bewerkstelligen van verandering en duurzaamheid is een onderneming die voortkomt uit de bezorgdheid zoals die gedurende de laatste tientallen jaren wordt geuit over de snel veranderende wereld die zich snel lijkt te verwijderen van de belofte om de mensheid (en nog veel meer) van een fatsoenlijk bestaan te voorzien. De drang om de kwaliteit van het milieu te beschermen vormt een belangrijke drijfveer in het Westen, terwijl de bezorgdheid voor het naakte overleven duidelijk aanwezig is in het Oosten. Zowel op het niveau van instituties als van individuen wordt een steeds groter wordende inspanning geleverd om veranderingen met het oog op duurzaamheid te begrijpen en te sturen. Terwijl beschavingen in het verleden diverse soorten gereedschap hebben toegepast, zijn sommige toch niet in staat gebleken om zich te handhaven. Het schrijven van dit proefschrift vindt dan ook zijn motivatie in de behoefte om gereedschap te onderzoeken en waar nodig te ontwerpen dat de mogelijkheid schept om in te werken op het domein van verandering en duurzaamheid.

Voor een dergelijke onderneming is het allereerst noodzakelijk om te onderzoeken wat de aard is van het gereedschap waartoe men gewoonlijk de toevlucht neemt als het gaat om de vraagstukken van verandering en duurzaamheid. Hoe kan dergelijk gereedschap onderling worden vergeleken? Hoe kunnen we vaststellen of een stuk gereedschap toereikend is? Dergelijke vragen dienen te worden gesteld teneinde inzicht te verwerven in het ontwerpproces dat leidt tot nieuw en adequaat gereedschap.

Elk concept kan worden beschouwd als een stuk gereedschap, en men kan het karakteriseren aan de hand van het betreffende structurele domein. Het deel van de werkelijkheid waarop het gereedschap kan inwerken (het zgn functionele domein) wordt ingeperkt door het betreffende structurele domein. Gereedschap kan dus worden beoordeeld op de mate van toereikendheid voor een toepassing op een bepaald gekozen gebied. Men kan ook nagaan in welke mate ze zijn gebaseerd op andere stukken gereedschap (of concepten), en of ze beperkingen bevatten die het gevolg zijn van het gebruik van secundaire vooronderstellingen in hun structurele domein (zulks in tegenstelling tot een structureel domein dat slechts primaire vooronderstellingen bevat). Geredschap stelt de gebruiker in staat om slechts datgene “waar te nemen” dat binnen de afbeelding van het structurele domein op het functionele domein valt. Zodoende wordt de mogelijkheid tot waarneming geboden, terwijl tegelijkertijd de gebruiker wordt beperkt tot het domein dat is afgepaald door de aard van het gereedschap.

Verandering is de constante trek in het universum. Waarnemers kunnen met behulp van hun gereedschap verandering observeren in de vorm van gebeurtenissen. Beschavingen streven naar het handhaven van een gewenste orde. Een dergelijk orde is zelf aan verandering onderhevig. De vraag naar duurzaamheid is derhalve de vraag naar het sturen van veranderingsprocessen. Typerende soorten gereedschap dat hiervoor is ontwikkeld, zijn het formuleren en oplossen van de vraagstukken in termen van problemen (“problem solving”), het gebruik van kennis-systemen en het hanteren van systeem-analyse.

Het gereedschap van “problem solving” is gericht op het formuleren en aanpakken van problemen. Deze zijn echter gerelateerd aan een waarnemer, met diens instrumenten voor observatie, en in een bepaalde context. Als één van deze parameters verandert (zoals ze zonder twijfel zullen doen), dan behoeven problemen niet langer problemen te blijven. Op z'n best komt “problem solving” neer op verplaatsing naar een ander systeem of naar de toekomst. Het resultaat is onvermijdelijk een spiraal van problemen en oplossingen. Dergelijk gereedschap is dus ontoereikend voor het beantwoorden van de vraag naar het sturen van verandering of duurzaamheid.

Het gereedschap van kennis-systemen is geschikt om in een grote mate van detail “kennis” en “informatie” over onderdelen avn de werkelijkheid te verzamelen. Aangezien niemand in staat is om een dergelijke hoeveelheid kennis op te slaan, te verwerken en te gebruiken, zijn collectieve opslagsystemen ontwikkeld (in de vorm van databanken, het opleiden van specialisten, etc). Deze aanpak is gericht op het overwinnen van de beperkingen die zijn gesteld aan een individuele waarnemer of aan het afzonderlijke meetapparaat. Toch lijdt ze ironisch genoeg aan recursieve versterking doordat de opslagvormen steeds weer zijn gebaseerd op andere opslagvormen. Daarnaast blijken dergelijke aanpakken behept te zijn met “problem solving” trekken. Er bestaat geen garantie dat de kennis of informatie ook werkelijk relevant is. Het is dus duidelijk dat dergelijk gereedschap ontoereikend kan zijn vanwege dit gevaar van irrelevantie voor het vraagstuk van het sturen van verandering of duurzaamheid.

Het systeem-analytisch instrumentarium onderscheidt functionele eenheden in de werkelijkheid. Het werkt dus op elementen die een directe functionele betekenis hebben. Het instrumentarium bevat geen gereedschap om een functionele eenheid te identificeren en laat de omschrijving van het systeem over aan de analyst. Daardoor zijn er slechts beperkte mogelijkheden om een inzicht te delen met anderen of zelfs de reikwijdte van een systeem eenduidig vast te stellen. Sommige onderdelen van het systeem-analytisch gereedschap zijn zelf gebaserd op ander instrumentarium of bevatten secundaire vooronderstellingen in hun structurele domein. Ze beperken daardoor niet alleen de reikwijdte van hun mogelijkheden, maar zijn dus ook afhankelijk van de juistheid van de (vooronderstellingen omtrent) het gereedschap waarop ze zijn gebaseerd. Dit gereedschap is daarom (in z'n huidige vorm) waarschijnlijk ontoereikend om de problemen van het sturen van verandering of duurzaamheid aan te pakken.

Vanwege deze problemen met het huidige gereedschap (omschreven in deel 1 van dit proefschrift) zijn in deel 2 nieuwe “tools” ontwikkeld die beter in staat zijn om de gewenste problematiek aan te pakken. De in dit proefschrift centraal staande gereedschapskist bevat deze nieuwe hulpstukken: Syslogic (of de logica van systemen) en de algemene theorie omtrent de organisatie van systemen. Syslogic is een hulpmiddel dat de gebruiker in staat stelt om systemen zodanig te definiren dat hun identificatie kan worden gedeeld met andere waarnemers. Syslogic biedt ook de mogelijkheid om het ontwikkelingspotentiëel van dergelijke systemen te onderzoeken. Hierdoor wordt het mogelijk om na te gaan of een gewenst potentiëel ligt binnen het realiseerbare of algehele potentiëel van een systeem.

Syslogic beschouwt systemen als bestaande uit een verzameling van actoren. Als een reeks van actoren betrokken is in een specificeerbare relatie tot elkaar, dan is sprake van een systeem. Elke verandering in de relaties tussen dezelfde groep van actoren representeert een systeem dat isovorm is in termen van de betreffende reactiviteiten. Elke actor reageert op gebeurtenissen door middel van inscipts. Identieke systemen met actoren die beschikken over verschillende inscripts worden isovorm in termen van respons genoemd. Als mbv Syslogic eenmaal een systeem is omschreven, dan kunnen verschillende isovormen worden onderzocht voorzover ze relevant worden geacht.

Syslogic biedt ook de mogelijkheid om de invloed van zowel interne als externe actoren op de bereikbaarheid van het potentiëel van het systeem vast te stellen. Het geeft zicht op de realiteit zoals die wordt waargenomen door de afzonderlijke actoren. Met behulp van Syslogic kunnen systemen worden afgebeeld in de vorm van samenhangende pictogrammen. Deze kunnen vervolgens worden vertaald in een wiskundige vorm door gebruik te maken van de computertaal NOW (speciaal ontwikkeld voor modellen in Syslogic formaat), hetgeen de betreffende wiskunde in hoge mate doorzichtig maakt. Op basis hiervan is een software programma, de zichtbare gereedschapskist, ontwikkeld. Deze bevat een vertolker voor de taal NOW, zodat simulaties met modellen in Syslogic kunnen worden gemaakt en onderzocht. Het kan dienen als onderzoekslaboratorium, als hulpmiddel in onderwijs, en als ondersteuning bij besluitvorming.

Aangezien systemen zelf voortdurend veranderen, en Syslogic niet in staat is om veranderingen in systemen op directe wijze op te nemen, werd het noodzakelijk om een algemene theorie omtrent de organisatie van systemen te ontwikkelen. Deze algemene theorie vindt z'n oorsprong in de noodzaak om bouwstenen te zoeken die kunnen worden gebruikt voor alle vormen van organisatie, los van hun fysieke samenstelling (of hun aard). De theorie is gebaseerd op de kenmerken van alle existenties. De wetten van organisatie geven elke existentie een identiteit, een rol, (een groep van) karakteristieken en behoudswetten. Elke existentie is een actor, en gebeurtenissen kunnen zelf actoren worden. De reactiviteit van elke actor bepaalt en beperkt de aard van de organisatie (of reorganisatie) die kan plaats vinden als een groep van actoren relaties aangaat. De orgatom (de simpelste eenheid van organisatie) is de existentie (actor). Het wordt dan duidelijk dat een organisatie zelf niet kan worden geschapen of vernietigd, maar slechts kan worden gereorganiseerd. Een systeem kan zo worden omschreven aan de hand van de betrokken actoren en hun reactiviteiten. We beschikken op deze wijze over een bouwsteen die kan worden gebruikt voor elk systeem dat zich organiseert in verbanden tussen actoren. Deze theorie kan vervolgens worden toegepast bij het ontwerpen van organisaties op een synthetische wijze, veeleer nog dan slechts als een analytisch hulpmiddel voor het doorgronden van systemen.

De algemene theorie is een hulpmiddel voor het onderzoeken van de levensloop van de organisatie van een systeem. Het biedt, wellicht voor het eerst, een bouwsteen voor alle vormen van organisatie, los van de fysieke aard van de organiserende grootheid. Dergelijke bouwstenen kunnen vervolgens worden gebruikt voor zowel analyse als synthese. Net zoals atomen zijn deze bouwstenen hulpmiddelen die een breed spectrum aan complexe structuren mogelijk maken. Het valt buiten de reikwijdte van dit proefschrift om ze alle te behandelen. Enkele interessante voorbeelden komen evenwel aan de orde in deel 3 van het proefschrift (en haar bijlagen).

De gebruiker draagt uiteindelijk de last bij het toepassen van dit gereedschap, of het nu gaat om toepassing voor onderzoek van, communicatie over, of zelfs sturing van de organisatie en/of systemen waarop het ingrijpt. Daarom worden in het proefschrift de gevolgen van het ingrijpen in de wereld getoond voor zowel onderzoek, communicatie als sturing. De algemene theorie laat zien dat de waarnemer (of de analyst) moet beschikken over reactiviteit met betrekking tot het waargenomene. Dit heeft tot gevolg dat in het slechtste geval de irrelevantie van waarnemingen kan worden vastgesteld, en in het beste geval nieuwe informatie over het ontwikkelingspotentiëel van het systeem in kwestie beschikbaar komt, indien de waarneming de waargenome isovorm niet doet overgaan in een andere isovorm. Toepassing als synthetisch hulpmiddel maakt het mogelijk om organisaties te construeren en hun stabiliteit alsmede hun bestaansmogelijkheden te onderzoeken. Dit zelfbewustzijn zoals het als optie wordt geboden door de algemene theorie, is in feite de reactiviteit ten opzichte van de eigen reactiviteiten. Daarmee wordt leren de kunde om reactiviteiten toe te voegen. De omgeving is in deze theorie het systeem. Hierdoor worden de vraagstukken van verandering en duurzaamheid tot beter beheersbare kwesties teruggebracht. Ook maakt de theorie duidelijk wat het contrast is tussen het handhaven van een systeem en de evolutie ervan.

Met behulp van Syslogic wordt het mogelijk om onderscheid te maken tussen drie niveaus van sturing: management van toestanden, die van verandering en die van relaties. De toestandsmanager wordt gedreven door gebeurtenissen, en kan de diverse alternatieven voor sturing van toestanden onderzoeken mbv Syslogic. De manager van veranderingen kan hetzelfde doen met de verschillende isovormen op basis van responsen bij het realiseren van de ontwikkelingsmogelijkheden van het beschouwde systeem. De manager van relaties kan diverse isovormen op basis van reactiviteiten bestuderen. De algemene theorie van organisatie van systemen biedt de mogelijkheid om nog een ander niveau van sturing te onderscheiden: management van organisatie. Managers van organisatie zijn gericht op het onderzoeken van de (bestaans)mogelijkheden van verschillende systemen in een voortdurend veranderende wereld.

Dit proefschrift biedt een beschrijving van het prototype van de gereedschapskist en van een eerste versie van een algemene theorie van organisatie van systemen, en heeft zeker niet de pretentie om een definitieve en finale versie van beide te geven. Het beoogt te functioneren als aanzet voor de ontwikkeling van gereedschap voor het sturen van veranderingsprocessen en van de ontwikkeling van samenlevingen in de richting van duurzaamheid.

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