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Strukturelle Arbeitslosigkeit, alarmierende Umweltveränderungen, wiederkehrende Anzeichen eines Börsencrashs, die Verstrickung in kriegerische Auseinandersetzungen: Angesichts einer immer komplexeren Welt wird die Unzulänglichkeit herkömmlicher Denkweisen immer deutlicher. Für sich perfekt geplant, können die Folgen jedes Eingriffs in vielschichtige Gefüge fatale Konsequenzen haben: Rückkopplungen, Zeitverzögerungen, Spätfolgen.
Über zwanzigjährige Erfahrung des Autors mit solchen Fragen ist hier zusammengefasst zu einem Praxisbuch für Politiker, Manager und alle anderen, die in solchen Zusammenhängen denken müssen und wollen.

Frederic Vester, Jahrgang 1925, leitet die »Studiengruppe für Biologie und Umwelt« in München, ist Fachmann für Umweltfragen und gilt als Vater des vernetzten Denkens. Er ist Mitglied des Club of Rome, vielfach ausgezeichnet und einer der profiliertesten Sachbuchautoren im deutschsprachigen Raum. Zu seinen zahlreichen Veröffentlichungen gehören: ›Denken. Lernen, Vergessen‹, ›Neuland des Denkens‹ und ›Crashtest Mobilität‹.

Frederic Vester

The art of interconnected thinking

Ideas and tools for a new approach to tackling complexity

A report for the Club of Rome

With numerous black and white illustrations

Malik Management Centre St. Gallen

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Preface

We are all aware by now that we live in a complex world. The very word 'complexity' springs readily to mind in connection with any description of our present situation. Wherever we find ourselves facing problems that we see as becoming steadily more numerous, we put those problems down to complexity or to our lack of ability to cope with it.

But do we have proper access to complexity; do we truly understand it? The attempt to accumulate and evaluate more and more information by electronic means and thus find a better way of dealing with complexity is increasingly turning out to be mistaken. We are piling up a huge amount of knowledge, admittedly, but it makes the world we live in no easier to understand. On the contrary, our masses of information tend to thwart such understanding, making us feel less secure. Human beings, after all, are not meant to be slaves to complexity; they should be in command of it.

Ever since 1972, when the first Club of Rome report, *The Limits to Growth,* came out, we have known (if we did not know already) that humanity inhabits a natural system where resources are restricted, a system in which we cannot do everything we want to do without putting the very existence of human society in danger. What is done or left undone at one point on the planet inevitably has repercussions on other regions. In the 'global village', no problem is remote any more; action taken or not taken today may affect the living conditions of generations yet unborn.

The great achievement of our colleague Frederic Vester has been to show us a way, with his biocybernetic approach (an intellectual course he has pursued consistently for years), whereby we might create living conditions for humanity that meet the criterion of sustainability.

In his book Vester not only sets out in a very vivid and comprehensible manner the theoretical scientific foundations of the kind of 'interconnected' thinking that this requires; he also, in a workshop report based on extensive practical experience, presents a fascinating survey of the

tools of learning available to us all (though particularly, of course, to those with responsibility for decision-making at the economic, social, and political levels) when it comes to creatively shaping our environment. Here the author is able to refer in particular to his Sensitivity Model, which has already been in use for many years and is still capable, in many problem areas, of providing solution strategies for the kinds of planning and action appropriate to systems.
Frederic Vester is right to speak of an 'art'. In fact, he cites many examples to show the limitations of tackling complexity analytically. It is much more a question of grasping reality by intuitive means (like an artist, as it were), using patterns with ill-defined outlines. His book gives us a sense of what complexity is, and it suggests a variety of methods by which each one of us, whatever his or her particular area of responsibility, can exploit complexity in a creative way, structuring it in such a fashion as to secure the future of the human race.
This book will also have a most inspiring effect on our work at the Club of Rome. It is our hope that the author's vitally important message will, like his previous publications, meet with a great response, and that his book will reach many interested readers, especially amongst our 'movers and shakers'!

Ricardo Diez Hochleitner
Honorary President
Club of Rome

Foreword

We live in a world whose 'ins and outs' our minds have always found hard to grasp, be those complex inter-relationships the food chains of living organisms, the intricate play of natural forces, or the widely interconnected nature of economic influences. The exponential growth in population and, in its wake, the increasingly invasive interventions (proclaimed as progress) in the economy of nature and the quality of human life that have resulted from technological developments have so increased the density of those interactions that, despite every advance in knowledge, they seem daily more difficult to understand. In such a situation, one's threshold of inhibition against having anything to do with complex events naturally rises.
However, mounting crises and environmental disasters have shown that it is high time progress was no longer measured in material or even technological terms but at a new level of thought entirely, a level better suited to the altered state of our densely populated planet.
On the threshold of the third millennium and in the light of the global situation that we have created in the space of a few decades it must be right, therefore, that we should pause for a moment and adopt a fresh paradigm dictated by the systemic laws governing this Earth of ours. Before we subject ourselves and our habitat to a process of development that is less and less controlled we should try to see our world as it actually is – namely, a network. We have developed huge technological potential; we should stop wielding it so insouciantly and instead make constructive use of it in the knowledge that we are dealing here with a system.
What we need is a new view of reality. We need to understand that much is connected that we see as separate, that the invisible ties that bind things together are often more important as regards what happens in the world than the things themselves. The fact is, wherever we intervene the effects of our interventions radiate outwards, disappear, resurface elsewhere in a different form, or produce indirect repercussions; the

system's own momentum takes over. Course-correction from point of departure is no longer a possibility. To grasp the effects of our interventions in a complex system, we need urgently to improve our understanding of the pattern of that system's interconnected dynamics.

My preoccupation with the interconnected-thinking approach and with the types of planning and action based thereon (which take their bearings from the cybernetics of viable systems and from their principles of control and regulation) extends back over more than a quarter of a century. The scientific and literary works that I have published during that period have been devoted exclusively to implementing and propagating those findings and to developing strategically useful aids and implements. Right from my early study for the City of Munich, 'The systemic context of environmental problematics' [*Systemzusammenhang in der Umweltproblematik*, 1970], and my 1976 study for UNESCO, '*Urban systems in crisis*', I tried to elaborate and communicate guidelines for a new way of dealing with complexity. In my main works, 'The age of cybernetics' [*Das kybernetische Zeitalter*, 1976] and 'New Frontiers of Thinking' [*Neuland des Denkens*, 1980], I extended that approach to global developments and made the first attempt to explore the different areas of our civilisation in terms of their position in the context of the whole. Simultaneously, I reviewed all those areas for existing jumping-off points for a cybernetic reorientation. To convey an understanding of 'Our world as interconnected system' was also the purpose of my travelling exhibition of that name. Other exhibitions, books, and strategy games pursued the same goal.

At the same time the importance of system dynamics received a boost from Meadows's *The Limits to Growth* [1972] and other Club of Rome reports as well as from the book by Ernst Ulrich von Weizsäcker et al., 'Factor four' [*Faktor Vier*, 1995]. The St. Gallen school that formed around Hans Ulrich and the works inspired by Matthias Haller at the St Gallen Institute of Insurance (using the Sensitivity Model developed by myself) and produced by many other comrades-in-arms including the Head of Planning at the Frankfurt Regional Association [*Umlandverband*], Alexander von Hesler, increasingly made me want to carry the concept of interconnected thinking and the paradigm of systemic viability beyond the academic sphere and make them available to a wider public.

In the meantime there no longer seems to be any need (in the European and American worlds at least) to campaign for a generalised environmental awareness. After the more and more frequent blows landed by natural forces in the last few decades, Francis Bacon's paradoxical dictum that 'We cannot command nature except by obeying her' has become self-evident even to those not directly affected. The importance of an intact environment as our most significant economic foundation is (in public utterances at least) no longer questioned. All of which reflects a degree of rethinking. In practice, however, nothing has changed. Under pressure from short-term necessities, our political and economic decision-makers show little sign of acknowledging interconnectedness – let alone of taking it into account in their plans and actions. Usually this is due less to a lack of goodwill than to a dearth of the necessary knowledge. As a result, we frequently make the mistake of sawing off the branch we are sitting on.

So the urgent need for interconnected thinking to become planning practice, coupled with the prior requirement that mounting complexity should be not shunned but actually exploited, has for me become more and more of a preoccupation. I was aware, of course, that the methods of planning and development based on such thinking had to be different from those used by a non-interconnected approach with its often counter-productive strategies. The accumulated errors of recent years have shown beyond doubt that the classic approaches to planning, whether in business, in regional planning, in development aid, or in environmental policy, have all failed (indeed, could not but fail) because of the increasingly complex network of effects and repercussions that they leave out of account.

It was to bring about some improvement here that I developed, with the Sensitivity Model, a user-friendly process that would successfully accomplish the leap from deterministic projections, vast accumulations of data, and closed simulation models to a biocybernetic interpretation and evaluation of system behaviour. With *The art of interconnected thinking* I hope to render that leap plausible and comprehensible in terms of a sustainable development strategy that is not only theoretically coherent but can be put to practical use.

I shall also, in Part 1 of the book (called 'Things to be avoided'), clarify the problems posed by mounting complexity and demonstrate the far-reaching consequences that an inappropriate way of dealing with complex systems has for our habitat and the economy based thereon. I shall be showing the typical fears and errors of goal-setting, methodology, and strategy that must be avoided in future. In Part 2 ('What our system requires') I explain the new way of seeing things that is needed if we are to have any chance of grasping complexity at all, and I set out the kinds of support we can draw on from organisational bionics and biocybernetics to enable us to deal better with complex systems. Making their first appearance in this Club of Rome report are examples typifying the unheeded complexity of the problem areas of nuclear energy and gene technology. Part 3 ('The Sensitivity Model') introduces the new tools and procedures that have been developed for this purpose. Here the way through to the networked approach and its novel instruments will be set out and examples presented as to how it might be implemented. The chapters of Part 4 ('The new way to sustainable strategies') are concerned with what problem-solving strategies can be derived from a Sensitivity Model for system-tolerable planning and action and how they can be put into practice effectively – again with new sections concerning a cybernetic security policy with an attempt at analysing terrorism and some radical ideas about cybernetic medicine.

So the 20 chapters of this book not only trace and analyse from the cybernetic standpoint the sources of error in the kinds of planning and business management still current today (which take no account of the interconnectedness of systemic contexts); they also describe a practicable way, available to every decision-making body, of harnessing the far-reaching possibilities of a planning and decision-making process characterised by interconnected thinking (not least along the lines of Agenda 21) for the political, economic, ecological, and social spheres.

Part 1-
Things to be avoided

Introduction

Our dilemma in dealing with complexity stems from the fact that our whole education tends towards drawing simple logical conclusions and defining obvious cause-and-effect relations. We learned little at school (and usually during our subsequent training) of networks of interconnections in open systems with their frequently acausal behaviour. As a result we tend to shrink from these, preferring to concentrate on matters of detail instead. This narrowing of our thinking leads to the errors most typically made in dealing with complex systems. Simple cause-and-effect relations exist only in theory; they have no existence in reality, where all is indirect effects, networks of connections, and time-delays. In the world of reality, these often make it impossible to assign causes, and this in turn (since the interconnectedness of the system has not been understood) makes it even more difficult to predict the consequences of any intervention.

The flight into modern information technology (in the hope that access to larger and larger quantities of ever more precise data will give us an improved understanding of complexity) is more likely to land us with information overkill than to facilitate genuine analysis. Planning based on that kind of assessment (precise but not interconnected) takes no account of feedback control loops, nor does it allow for anything going wrong, since it provides for no cushioning. It is not 'error-friendly' (Weizsäcker's term *fehlerfreundlich*). The next five chapters set out to illustrate some typical cases of non-systemic goal-setting, methodology, and strategy, showing where and why such an approach will inevitably fail. Part of the blame for this lies with unthinking application of the growth paradigm and associated goals, which has its own chapter as do those ever-popular projections. Both are valid only within a time-horizon specific to the system concerned; they have their limitations so far as interconnected systems are concerned.

1 • Fear of complexity

Complexity has a great deal to do with interlinked networks; in fact, it owes its very existence to them. So complex processes, if they are to be understood, call for the kind of thinking in contexts that takes its bearings from the structure of organised systems and their specific dynamics. A lot of people seem to have a problem with this. And the reason is not only the usual fear of any change in tried-and-tested patterns of thought; it is also a fear of complexity itself, which we feel incapable of dealing with. As soon as interconnected thinking is mentioned (none of us had any trouble with this at pre-school age; our first experience of the world was of an entity not divided into compartments), many people feel that it is something foreign to the human mind, something that must be learned from scratch. Indeed, we are reluctant to take any account of interconnected networks, preferring to concentrate on the particular, on what we can grasp in concrete terms, rather than on higher contexts and on those invisible connections between things that go beyond the particular.

So we bury our heads in the sand and believe, for instance, that the best way of overcoming problems is by tackling them where they occur. In a complex system, however, getting rid of a problem *in situ* (rather than allowing for the systemic context) usually has the effect of creating two new problems instead. This explains why, in more and more parts of the world, despite many earnest attempts to master the mounting flood of problems in a non-interconnected way, the economic and ecological situation is already in a state of collapse. And since it is usually a question of indirect effects, which only appear after a certain delay, the causes are often not obvious; we look for them in the wrong places and the spiral goes on turning.

In other words, we cling to the illusion that we are still, as in an earlier age, free to make whatever plan we like for shaping our world and, if the technology is available, put those plans into operation. The fact is, our habitats and ecosystems, our water, air, and soil, did for many thousands of years possess sufficient cushioning capacity to balance out

(usually without adversely affecting humankind's ability to survive as the dominant species) every assault that the human race made on the environment. Today, with a word population of 6 billion, a kind of feedback loop ensures that, sooner or later, each assault on the biosphere will eventually redound as an assault upon ourselves. We are always both agent and recipient at one and the same time. Never before has humankind so thoroughly penetrated the world with its means of communication; never before has it been so inextricably implicated in every sequence of events on this planet. Wherever we look, we are involved; economics, politics, and technology are all in play. And however remote an event (a technological advance in Japan, deforestation in Brazil, or the founding of a sect in the USA), it touches our economy, our climate, our way of life even if the effect cannot be felt at the moment. Today's climate changes and the exponential rise in the frequency of the disasters triggered by storms, floods, droughts, and forest fires do not in fact reflect what we are doing today but may be the consequences of the way we went about things in the 1970s. And many of the consequences of our present-day interventions will only be felt (but then perhaps felt very much more drastically) by our grandchildren.

At any rate, the fact that for centuries the non-interconnected intellectual starting-point was sufficient to ensure our survival on this planet does not mean that we can go on using it. Granted, in certain areas of activity such as machine-building or parts manufacture it is still useful today, and in connection with specific stages of complex projects it is frequently indispensable. However, this way of proceeding (what we might call the technocratic-constructivist approach) has already reached its limits when it is a question of putting that machine to use and hence of intervening in the complex humankind-environment system. All it can do is comprehend parts of a system and their linear-causal mechanisms. There, its achievements may be outstanding, but its neglect of the holistic character of the system is criminal.

In an age of highly complex structures and processes (of 'networks', to use another term) it is thus absolutely crucial that we transcend the simple linear approach and that in our thinking, planning, and acting we not only become aware of the complexity and interconnectedness of our world but learn to exploit them in order to be able to act in a sustainable (i.e. evolutionarily meaningful) manner. Otherwise we are likely to feel less and less at home in our increasingly complex world and to fail more and more miserably in our intentions. Certainly, our thinking and our management are going to have to evolve.

So the dilemma of decision-making in the worlds of business, finance, politics, and administration lies in the fact that on the one hand there is a growing understanding of the need for a holistic way of seeing things but on the other hand (often out of sheer helplessness) isolated treatment of individual areas nevertheless persists. Our reluctance, when facing important decisions, to get to grips with complex systems and the cause-and-effect structures underlying them is further reinforced by two factors. In the first place, the number and degree of interconnectedness of the influence values that affect what we do are increasing daily, strengthening the impression of impenetrability. But so is the rate of such change accelerating to such an unprecedented extent that the readings are different every day.

Lack of training in systems theory

One way of bringing that situation under control would be to provide more training in 'systems theory' with its awareness that a particular specialism must always be embedded in the overall context of the relevant sphere of influence and habitat. Briefly, interconnected thinking needs to find an appropriate place in schools and further education as of today. Because in future those of us not trained in the subject will undoubtedly find it even more difficult to interpret the mosaic of actual interactions and to cope with the rules that govern them.

However, while thinking in terms of contexts is a prerequisite for the future it will not solve our problems on its own. Such thinking also needs to be implemented in planning terms and converted into action. For that, new kinds of instrumental back-up are required. The fact is, here too we encounter a major threshold of inhibition. Huge amounts of money and time are already being spent on the methods of system analysis already available. We are afraid of drowning in data yet still being unable to capture as much data as we need to, quite apart from the

many cross-connections. The result is a fresh capitulation in the face of complexity. The argument often ends: 'Even in my own specialist area I can no longer tackle the sheer volume of data thrown up by modern developments; how am I going to find my way if psychology, politics, communications technology, transport, or perhaps construction are added too?' In their frustration, people who actually find themselves faced with complexity prefer to fall back on the old 'linear thinking', taking refuge in individual expertise and thinking, 'At least here I'm on sure ground.'

The limits of the detailed breakdown

As soon as we go into detail, no matter how small our specialist area we shall sooner or later be overwhelmed by data. Not understanding the nature of systems, we also fail to find the right level of aggregation, taking account not only of higher systemic levels but also of indicators of sub-systems. Because how far are we to take the breakdown into detail; where does the limit lie? For instance, to understand the breeding behaviour of a type of water bird there is absolutely no need at all to record the feather count, research blood-pressure and renal function in ducks, or establish the dimensions of grains of mud and how the nest material fits together. And even if you did take all that into account, the resultant degree of refinement would again be an arbitrary choice. One might as well determine the chemical composition of eggshell, even descending into the atomic realm. Basically, such a breakdown into detail would have no end, and the possibilities of interaction would be infinite. Ultimately, a workable degree of complexity, somewhere between the atom and space, will always need to be chosen if a system is to be described. The question of the level of aggregation at which we must operate when capturing a complex system in order to be able to know how to deal with it satisfactorily, meaningfully, and also manageably will be described in detail in Part 3.

What matters is not the amount of information but making the right choice. This is a universal truth as regards the flood of information currently overwhelming us. Information is often seen as the Holy Grail of the future of humankind. The phrase 'the information society' that is bandied about as the great novelty, particularly in political circles (as if as social animals we have not always been an information society), is starting to become the great absurdity. The fact is, in our euphoria at this expanded access to total information we are forgetting that the wealth of information available to everyone all the time has got quite out of control, only increasing our fear of complex states of affairs. Possessing more information certainly does not mean being better informed. However, since so many people think it is, the supposed way out of the dilemma of complexity leads to multiplication of the amount of information available. As a result, fear of data overload paradoxically leads to even more data being captured.

Reluctance to accept 'soft' data

Another thing lacking in our comprehension of complex systems lies in a one-sided choice of the components that make up a system. In our obsession with 'safe measurements' and the modern techniques available to feed that obsession, it is first and foremost those data that are (or happen to be) measurable that find their way into our understanding of a system (if there has to be a choice of data, we think, then let us if possible go for 'safe' data, data that can be expressed in numbers). Qualitative factors, so-called 'soft' data, are left out of account, despite the fact that as regards the way a system behaves they play quite as large a role; indeed, as regards understanding what happens within a system they are often of even greater importance. It follows that a system captured in this way is fundamentally mis-described – for the simple reason that large parts of the system have been left out.

This reluctance to handle 'soft' data is very common. It reflects a wider fear of dealing with complexity. People are afraid that in allowing for such qualitative factors as subjective opinions, antipathy, prestige, attractiveness, beauty, capacity for reaching agreement, sense of security, and the like they are abandoning the 'safe' ground of scientific observation. They forget that saying things about a system that take no account of key parts of that system is very much more unscientific.

Pattern recognition

Here we come across one of the cardinal errors in assessing what is important as regards capturing complexity. This is about the 'face' of reality; it concerns what is called 'pattern recognition', a form of processing information that computers still find extremely difficult. The fact is, as regards pattern recognition the kinds of measurement that can be captured numerically are particularly unhelpful. Instead of believing that with them we are on safe ground, we ought actually to guard against them. Why? Because they pretend to be 'reliable', whereas as measurements of 'variables' (values that can vary, in other words) they play only a provisional role in a dynamic, open system. As measurements taken in isolation, they may be overtaken (become false, that is to say) a moment later, and if they are treated as fixed values they may perpetuate errors. Far more meaningful in terms of pattern recognition are the relations between the components of a system. Even if the components themselves change, such relations continue to determine the picture. They are far more 'reliable' than any measurements might be no matter how precise.

Classic mistakes

To illustrate the sometimes disastrous consequences of our fear of approaching complex contexts in an appropriately complex manner, a series of classic examples might be cited (as I have already done in detail in some of my books). They include many failed projects from the field of development aid: the campaign against sleeping sickness in cattle, for instance, which as a result of the excessively large herds to which it led resulted in overgrazing and desertification; the boring of deep-water wells that lowered the water table and made drought conditions even worse; badly thought-out dam projects (Aswan, Balbina), where damage outweighed benefit; river diversions and monocultures, which for example led to Lake Aral silting up (as had in fact been calculated), the fish-catch quotas that, through leaving climatic conditions out of account, undermined the Peruvian economy.

In the industrialised countries, too, the question of why so many strate-

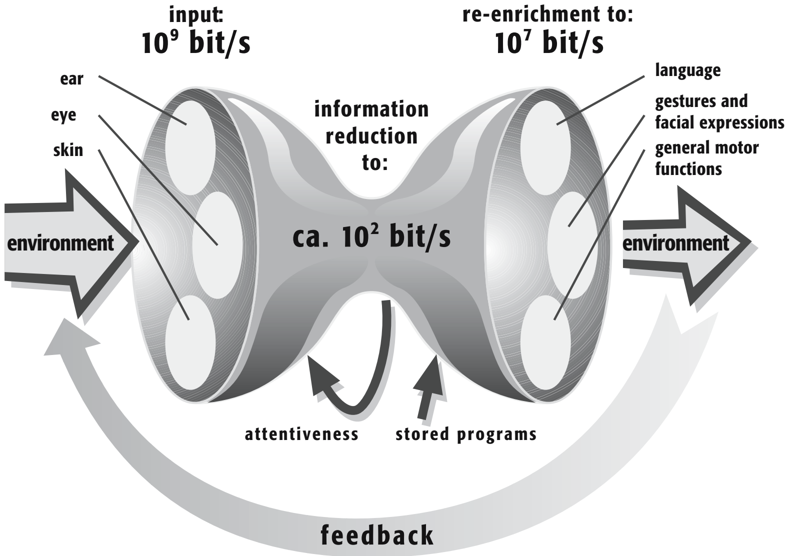


fig. 1: **The bottleneck of data reduction**: (*left*) information flowing in through the sense organs: input of approximately 109 bits/s; (*centre*) reduction by selection and pre-processing outside the processes of perception, whereby information is reduced to a ten-millionth part (!); (*right*) re-enrichment through processes of association in the right half of the brain (using materials already available) to approximately 107 bits/s (after Becker-Carus).

gies founder nowadays finds its answer in their failing to take account of complex states of affairs despite (or because of?) the fact that an ever-greater quantity of data is available to our planners. Having that much data in advance should really have enabled us to predict just how our plan would pan out.

In reality, however, that is precisely not what happens. Perhaps we need to ask ourselves why it is that nature has no problem with complexity. Nature clearly manages its mighty data stream without difficulty, so could it be going about things differently from ourselves? How does nature do it, controlling with such elegance and assurance the flow of the rivers of information continuously passing between its highly complex systems?

In answering this question it is instructive to know that a major information-processing function in living systems (and hence also in our brains) is precisely not to capture as much as possible of the data

streaming in through the sense organs but drastically to reduce its quantity. The fact is, for instance, our central nervous system deals with the information bombarding it non-stop from the environment quite differently from the way in which we, using our modern information systems, tend to operate.

The goal of brain activity is actually to minimise data, not to capture as large a quantity of it as possible. In this way the stream of information flowing into it through the sense organs undergoes selection and pre-processing and (without our having any awareness of this) is initially reduced to a millionth part of the amount received before being built up again subsequently by processes of association and resonance with the brain's own information. As a result, the information coming in from outside is first stripped of its irrelevant ballast and then, below the level of consciousness, kitted out in new togs (personalised, as it were) by information already present in the brain. This is brainwashing in reverse: here it is not the brain being washed but the brain itself washing the incoming flow of information. This 'bottleneck of data reduction' symbolises a central function of all living creatures, the object of which is to apprehend reality as a whole with just a few organising parameters, to recognise its 'face', so to speak. It is a crucial ability as regards our very survival on this planet, but one of which we make unfortunately little use. However, if we switch off that ability when we pass to action (as still happens today in the case of most specialist planning operations, with their data overload), no wonder our actions sometimes go awry.

Our IT is off course

The way in which our computers are currently programmed and the Internet itself, for instance, is structured goes in quite the wrong direction: instead of leading to a selection of information it leads to what we call 'information overload'. Consequently, most of the achievements of our IT specialists and the fact of worldwide access to ever-increasing amounts of data via the Internet constitute purely linear advances. Such advances have been made in good faith, for it is believed that coping with the complexity of the system largely demands more and more detailed information and that generic classification will be quite adequate. Yet ever-increasing amounts of data, like mounting traffic density, ultimately lead to chaos and hence to inefficiency. Certainly there can be no question of improved control of complexity as a result of rapid automatic data-transfer. The benefit of information clearly lies in selection rather than plenitude, in its relevance, not in its rate of transfer. If we are to work out strategies appropriate to systems, we must also reset our IT course. That course must assist us rather than parade as many points as possible. And if it assists us it will also help us overcome these fears of complexity.

What is a complex system?

However, the first thing to sort out in connection with any interconnected approach is whether we are dealing with complex systems or merely with parts of systems or even individual mechanisms. So let us take a brief look at what basically differentiates systems from individual things. Like any organism, a complex system consists of a number of distinct parts (organs) that co-exist in a specific dynamic arrangement. They are connected together in what we call an effect system. In this it is impossible to intervene without altering the relationship of each part to every other and hence the overall character of the system. Furthermore, real systems are always open, maintaining themselves through a constant interchange with their environment.

Parts of a system may also form a system or sub-system in themselves. Conversely, if a number of previously separate systems become closely interconnected a new, higher system may emerge. However, whether such a system will be viable and capable of surviving permanently depends on how far its organisation obeys (or flouts) certain basic principles of biocybernetics.

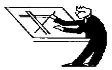
Through its ability to recognise pattern the right half of our brain tells us that we are dealing with systems, and we unconsciously sense when isolated consideration of individual areas needs to be abandoned in favour of a holistic way of looking at things. Nevertheless, the left half of our brain likes to make us think that, in connection with building a good road, constructing a functioning factory, or training top experts, all these factors also need to interact. And then we are surprised that things suddenly start to rock violently and delayed consequences appear somewhere else entirely or prove mutually incompatible. Planned to perfection in their own terms, the various parts may well interact to cause chaos.

The problems with which we are increasingly confronted are not ones we can get a grip on with science and technology alone (no matter how high a standard they attain), nor can we guard against the risk of failure by entering them in the equation (no matter how precise their values). On the contrary, unexpected reverses will in practice more and more often take us by surprise; the fact is, complex systems behave differently from the sum of their parts.

Complex is not the same as complicated

So we must move on to understanding the behaviour pattern of complex systems in the same way as we do the functions of an ‘organism’, developing strategies that embrace the interaction and self-regulation of the components of the system (the system’s ‘evolutionary intelligence’, so to speak). That kind of thing can be practised. Because complex does not necessarily mean complicated, and understanding systems is not in essence any harder than understanding individual phenomena; it merely calls for different prerequisites and different tools. With a new approach that is appropriate to systems and using quite different tools from those employed in previous methods of management, it is possible to grasp even complex systems with a few key variables, to understand better how they behave, and to deal with them differently.

The findings to be addressed in greater detail in the ensuing chapters (findings extracted from organisational bionics regarding the management methods of nature) can go a long way towards furnishing models for a more meaningful use of modern informatics. The object must be to cope better with the increasingly complex problems of planet Earth – better at any rate, than we have clearly been able to do with our usual non-interconnected view of things. That view has led to a growing denaturation of our eco-systems, rendering our economic, political, and social systems more and more fragile. Unless we turn our backs on the current blithe belief in progress, it is only a matter of time before the very foundations of our lives become destabilised.

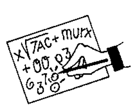


Why new decision-making tools?

Experience shows that in connection with a complex system such as a company, a development project, or traffic in towns it is actually impossible to plan or develop individual areas separately. Yet we continue to do so.

Complex systems scare us!

The fact is, as soon as we peer beyond the end of our noses we panic, fearing that we are about to drown in data and that we shall never be able to understand all the cross-links. Instead of practising the right kind of 'interconnected thinking', when confronted with complexity we too readily fall back on familiar 'linear thinking'.

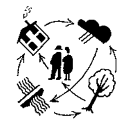


We think that perfection of detail is enough

In other words we believe that, when we build a good road, construct a functioning factory, or train top experts, all our perfectly detailed factors must interact in the right way.

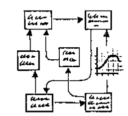
But interaction eludes our grasp!

And then we are surprised that things suddenly start to rock violently and delayed consequences appear somewhere else entirely or prove incompatible. Planned to perfection in their own terms, the various parts may well interact in such a way as to cause chaos.



The fact is, complex systems behave differently!

So we must move to developing strategies that embrace the interaction and self-regulation of the components of the system. That kind of thing can be practised. Because complex does not necessarily mean complicated, and systems are no harder than individual phenomena – they are simply different.



That is why we need a new approach

Grasping complex systems, understanding better how they behave, and dealing with them in a different way calls for a new approach to planning – one that takes account of the cybernetics of the system concerned.

A crossroads in our thinking

We do indeed, at the start of the new millennium, find ourselves at a real evolutionary crossroads as regards our thinking and hence also our thinking machines. Our brains, at any rate, are not up to processing the wealth of information available to us via global networks, let alone making meaningful use of it. Consequently, we find ourselves obliged to have not human beings but computers themselves receive and process the information flooding in from data banks. We ourselves are none the richer for it, either in terms of knowledge or in terms of understanding. Thus automated, the information simply passes us by.
We can gain an initial impression of what is happening currently from the stock market, when on the basis of programmed limits buying and selling fluctuate automatically, as it were. The last decade of the twentieth century saw several partial collapses such as those of Baring's Bank and several Japanese banks and, in 1997, the near-explosion of the largest hedge fund, prevented only by a major intervention on the part of America's central bank (the fund's losses suddenly exceeded 100 billion dollars, which almost destabilised the entire banking system). All these

phenomena represented typical positive feedback loops that, particularly when their course is automatic, are capable of accelerating not only upwards but also (and quite as much) downwards. All it takes to recognise this is a little cybernetics, but cybernetics is something of which those involved clearly have no idea. The possible future consequences in his respect of the chaotic movements of the Nasdaq exchange, which deals in entirely virtual Internet stocks, in terms of their effect on the international finance market and the world's economies are not readily foreseeable. Here too there can be no question of enhanced control of complexity as a result of automatic data transfer.

Let us pause for a moment and summarise what has been said up to now.

In our perception of reality there is a level that we face with mounting helplessness: the increasing complexity of the world we live in. It seems obvious that our mental apparatus is no longer a match for the dense network produced by exponential population growth and the activities that go with it. The proof is that more and more of our political and economic decisions are going wrong. Yet the behaviour of both natural and artificial systems is not unfathomable. There is something we can do about the impotence we feel. Our fear of complexity can be overcome though not in the way we think. What we need is not more information but the right selection of information. Just how useless it is to focus on individual parts of the picture (in the hope of thus being able to escape data overkill), and on the typical mistakes we make, no matter how precise our calculations, in our dealings with ourselves and the world – these are things that the next chapter will make clear.

2 • Errors in dealing with complex systems

Whatever problems we may encounter in adopting an interdisciplinary way of looking at systems and an unfamiliar approach to complex systems, there is no point in our trying to facilitate the decision-making process by simply ignoring the complexity of our environment. We can no more escape it than we can escape the complexity of our own nature. Above all, we must accept that we are ourselves far more intimately involved in the complex systems of our environment and the biosphere we inhabit than traditional linear cause-and-effect thinking (which, moreover, divides the world up into compartments) would have us believe.

It is not a case of humans being here and nature there; we ourselves are nature, together with all the technologies we have devised. Mounting social burdens, a rising toll of environmental disasters, economic crashes, the emergence of previously unknown illnesses such as AIDS and Alzheimer's disease, and the proliferation of allergies, cancers, and circulatory disorders give us all, in one way or another, personal experience of the fact that every operation that we perform on the biosphere is ultimately an operation performed on ourselves. We are all, as I say, simultaneously agents and recipients. The only thing is, we are usually unaware of this because a long latency period often conceals such repercussions until very much later – when of course we feel them all the more dramatically, not just in terms of altered health and quality of life but also economically and financially.

The way ecosystems react to steadily rising consumption of resources and manipulations of the foundations of life, which are manoeuvring us into a more and more difficult socio-economic situation, are for the most part (aside from a few isolated responses) helplessly accepted. Since in connection with complex systems the consequences (those resulting from the greenhouse effect, for instance) do not as a rule follow immediately upon the causes and are often only indirectly linked to them, many decision-makers feel that no immediate action is required. Action to avert the situation (as climate conferences have been showing

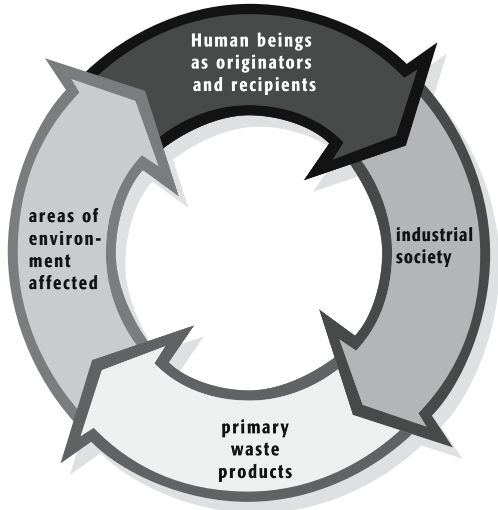


fig. 2: In the global cyclical process, humans are simultaneously originators and recipients of environmental changes that proceed from them.

for years) is shifted upstairs to the international level, where it becomes a subject of more or less fruitless debate despite the fact that, for a major portion of its inhabitants, such inaction threatens to make our planet less and less hospitable.

There is of course one branch of the economy that has been forced to acknowledge these mounting setbacks: insurance companies and among them in particular reinsurers, whose loss accounts as a result of environmental disasters have quadrupled since the 1980s and who represent one of the first branches of the economy to have adopted a clear response. From this quarter at least there is no doubt about the contribution of man-made influences, but in the wider world there is a huge knowledge deficit with regard to the reciprocal effects generated by our interventions in any system. There is far too little understanding of the way in which inherently impeccable plans for an industrial area, for instance, or a transport system can, if the interconnections have been disregarded and those plans drawn up in isolation from the superordinate system, lead us into disaster not only ecologically but also so far as their social sustainability and financial viability are concerned. Nor will it make much difference whether the by now normal precautions against direct pollution of the environment have been observed.

Take just one example. Building a new dam does not merely affect energy consumption, water retention, the water table, and the newly-flooded ecosystem; it also shifts the direction of the receiving water, changes land use and hence local industry, and has repercussions on tourism, road-building, and traffic volume; last but not least it produces social repercussions with regard to structures of employment and resettlement, which in turn feed back into political acceptance – all factors that only if their systemic interconnectedness is respected will decide whether the scheme succeeds or fails. Or whether, indeed, it ends in disaster.

Think of the Balbina dam in Brazil: a vast lake of virtually stagnant water, 236,000 hectares of rain forest wiped out, millions of wild animals killed, the habitat of indigenous tribes destroyed, famine and disease visited upon riparians – and all for a mere 80 megawatts of power, for which there was in any case no concrete demand! Even with those responsible for building Balbina now admitting that the whole undertaking was a catastrophe, there are already other, similar prestige projects under construction with the backing of politicians and banks.

Such failures can surprise us only if we ignore the facts or actually deny that the whole is more than the sum of its parts. As soon as an open, complex system forms as a result of interaction of its parts, what happens in reality is that qualities suddenly appear that did not exist before and are not even contained in that system's individual components. I am thinking of feedback effects, threshold values, self-regulation, and tipping-points. They lend the system an individual character and lead to a specific type of cybernetic behaviour. This appearance of so-called 'colligative properties', already familiar in elementary particle physics, certainly holds good for complex systems.

In other words, once such a system has come into being we can no longer deduce its reactions from the individual components that make it up. Its very ability to survive does not emerge therefrom; the fact is, we are now dealing with different laws, systemic laws, which are laws of nature as fundamental as, say, the laws of the conservation of energy. And they are entirely capable of messing up many a good intention.

As a result, a plan that is formed and implemented in a deterministic manner, without feedback with the environment (insulated against disruption, so to speak), often has little chance of survival, indeed is in far greater jeopardy than if it came about in open contact with the environment. It is not insulating against disruption (the kind that comes from ignoring interest groups, for instance) but in fact allowing for it at the conception stage that will give the plan additional error tolerance. Installing cybernetic self-steering gear early on will ensure that subsequently, even if whatever can go wrong does go wrong, the whole thing will still perform its function – just like a living organism. A living organism is not constructed; it comes into being. And it does so in a state of constant feedback with its environment. To take a typical example from the field of medicine, without early contact with pathogens the human immune system cannot develop, and a child brought up in strictly sterile surroundings will readily, in later life, fall victim to a bacterial infection.

Since we pay no heed to or indeed positively suppress such basic facts of complex systemic contexts in our plans and projects, in practice we are more and more frequently surprised by unexpected setbacks such as the experts had in many cases thought would never occur. One thinks of the still ever-present threat of famine in certain developing countries in spite of (or should one say 'because of'?) the 'green revolution', of the increasingly common floods and landslips in spite of (or because of?) canalisation of streams, reinforcement of banks, and securing of slopes, of encroaching desertification in spite of (because of?) modern methods of irrigation, where dams and river-diversions contribute towards the restructuring of entire habitats. And then there are the technological setbacks: the ruptured supertankers, reactor accidents, disastrous fires such as those at Düsseldorf Airport and in the Tauern and Mont Blanc tunnels, the shocking derailment of the German InterCity Express, a train fitted with the very latest safety technology, the crash of the supersonic airliner Concorde, and still, year after year, the equally shocking serial carnage on the world's roads, which at 750,000 dead and 10 million maimed approaches world-war proportions. And all in spite of (or is it actually 'because of'?) improved performance, high-tech safety, ABS, and airbags? Or think of the steady toll of bankruptcies in American agriculture (with at times between one and two thousand farmers going out of business in a single week), the temporary collapse of the European beef market as a result of BSE, or the dioxin scandal in Belgium's poultry trade, when birds were given inappropriate feed derived from refuse – all in spite of (because of?) the most rational agro-industrial methods. One could go on for ever, the list is growing longer by the day, and all these things are undesirable consequences of a technocratic (that is to say, non-cybernetic) way of doing things that fails, in its planning procedures, to take account of the way systems behave.

Even where no criminality is involved it is possible (despite the collaboration of highly-paid experts) for the most detailed plans to spawn invisible interconnections, creating problems in places where we had not expected to see any. In short, our ubiquitous science with its linear approach and its process of 'full' data-capture has not, to date, been able to surmount one snag: that despite (or ought we again to say 'because of'?) immense expertise environmental problems and their socio-economic consequences are clearly causing us not less but more trouble than ever before. No wonder the belief that the world we live in will be made safer and more tolerable by science and technology has taken some pretty bad knocks.

In fact, many have begun to doubt whether we can emerge from our present helplessness in the face of such complexity and successfully adopt a new basic attitude that will deal with complex systems in a different way, learning to exploit the opportunities they present. Probably this will require of our western industrialised countries a conversion as radical as that which, towards the end of the last century, turned the East against Communism. But if our habitat is to remain habitable we have no alternative: we must find our way through to an entirely different way of looking at reality, and in Part Two of the book we shall discuss this in more detail.

But before we do that, we need first to take a closer look at our cardinal errors in dealing with complex systems. The fact is, like the fear we identified in our first chapter, this too is based neither on ill will nor on a lack of intelligence; to a great extent it stems from a long prevalent but nowadays no longer valid constructivist view of the world, which overlooks key interdependencies.

Our cardinal errors in dealing with complex systems

One of the most interesting experiments regarding our inability to solve problems in complex systems was carried out in 1975 by systems psychologist Dietrich Dörner and first described in his book 'Problem-solving as processing information' [*Problemlösen als Informationsverarbeitung*]. He invented a fictional African region called Tanaland and stored its principal data and influence factors (which were taken from actual conditions in parts of Africa) in a computer. A dialogue program was developed to go with the data, and twelve persons from different areas of expertise were assigned the task of ensuring that in entirely general terms things went better for the people of Tanaland, with relevant loans being provided by the World Bank.

With these they could sink wells, build dams, install industries and power stations, improve medicine and hygiene, change types of cultivation and habits of fertilisation, and even alter hunting traditions (by supplying arms). In this way the country could be controlled through several levels of decision-making, where the consequences of actions taken previously were always available, covering the course of an entire century.

What came out was more than devastating. Instead of people's lives becoming steadily better, which had been the aim, brief periods of improvement were succeeded by disasters and famines. Herds shrank to a fraction of their former size, food sources became exhausted, and finance dried up; loans could no longer be repaid. What was striking was that everyone involved in the experiment, experts included, created chaos and ran the country into the ground – although they had all wanted the best.

Dörner, however, was not interested in saving Tanaland. As a psychologist he was far more concerned to find out why so many of our decisions have this tendency and what our biggest psychological difficulties are in this connection. From his observations there crystallised out the principal errors of thought and planning that we usually commit in dealing with complex systems. In further experiments (the 1983 Lohhausen project) and books (*Die Logik des Misslingens,* 1989; translated into English as *The Logic of Failure*, 1996), Dörner has been able to develop his description of these mechanisms and the 'logic of failure' that lurks within them.

Six errors in dealing with complex systems

(with acknowledgements to Dietrich Dörner)

First error: False description of goals

Instead of setting about enhancing the system's viability, Dörner's people tried to solve individual problems. They felt the system all over until they found something wrong. This was removed. Then they looked for the next thing wrong, and maybe they already corrected a consequence of the first intervention. It's what you call a patch-up approach. Planning takes place with no guiding policy, like a beginner playing chess.

Second error: One-dimensional analysis of situations

Some test subjects consistently gathered large amounts of information, which generated long lists without producing a structure. In the absence of any organising principles (feedback controls, say, or threshold values – that sort of thing), there could of course be no meaningful evaluation of the masses of data. They refused to grasp the cybernetic nature of the system (its historical origin, for instance). Consequently, the dynamics of the system remained a mystery.

Third error: Irreversible foregrounding

They insisted on a single point of emphasis, initially acknowledged as correct. However, it became their favourite. To start with, it proved successful, so they clung to it, neglecting other tasks. That meant that what they did had grave consequences in other areas, even causing them to overlook already existing problems and shortcomings.

Fourth error: Neglected side effects

Caught up in linear, causal thinking, people pursued their search for measures to improve the situation in a very single-minded manner – that is to say, without analysing side effects. In many cases they did this even after recognising that the system was an interconnected structure. If you like, they applied no policy test (no 'what-if' test) to subject potential strategies to a thorough trial.

Fifth error: Tendency to oversteer

One approach that Dörner observed often was this: Initially, people showed hesitation; they set about eliminating shortcomings with minor interventions. When nothing happened in the system as a result, the next step was a major one – followed by a slamming-on of the brakes as soon as unexpected repercussions occurred (meanwhile, because of the delay, the first small steps had accumulated unnoticed),

Sixth error: Tendency towards authoritarian behaviour

The power that came from being allowed to change the system and the belief that one 'had it sussed' led to the kind of dictatorial approach that is wholly inappropriate for complex systems. For these, the most effective approach is not to swim against the current but to swim with it, making changes as you go. And there was another element in taking giant steps of a sort that jeopardised the system's structure: the dubious hope of acquiring personal prestige and gaining power and respect through the size of a project rather than through whether or not it works better.

These errors, taken together, probably explain the shattering outcome of the Tanaland experiment. Every one of us will find similar errors in his or her own field of decision-making; because regardless of whether one is planning for a regional or local authority, for a traffic system, or for a company, in each case one is dealing with complex systems in which interventions that take no account of the system as such may produce similarly negative effects.

Unfortunately, these intellectual errors also drive many decisions about war and peace – even today, when surely those responsible have access to all the data regarding political relations. Since the Second World War (and despite the ghastly experience gathered from that episode), there have been some dramatic examples of unfortunate military action: from Vietnam to Somalia to Chechnya to Kosovo. Particularly as regards this recent example of a campaign carried out by an armed force (NATO) equipped with the latest technology, it would be worth examining the mode of procedure and what it led to in the light of the intellectual errors that Dörner identified. One would undoubtedly conclude that rarely have all six errors in dealing with complexity been more flagrantly committed than in this case. In fact, the German Peace Research Institute branded the strategy employed in the Kosovo conflict as 'narrow-minded, contrary to international law, and unsuccessful'.

In the second Club of Rome report, *Mankind at the turning point* (1974), Mesarovic and Pestel write: 'There is no doubt that cybernetic systemic strategies are for the moment less popular than simpler linear strategies. However, since the reality surrounding us does in fact constitute a complex system, we are simply deluding ourselves if we think we can gain control of the situation using inadequate strategies. This makes developing and applying suitable systemic strategies the key element in dealing with problems. Here again, basically only outline (i.e. not detailed) plans of action will permit realistic strategies. The fact is, complex systems require constant dynamics in terms of thinking and hence an extensive and varied heuristic structure (= the totality of the "finding-out process" at a person's disposal).'

Instances of non-interconnected action with consequent repercussions are almost too numerous to mention. The main problem in connection with all planning mistakes is clearly that, while qualified experts are invariably involved, their qualification goes no further than the frontier of their individual field of expertise. Beyond that, they are usually clueless; certainly they have no overview of the cybernetic interconnections of their particular project.

How do these errors come about

This brings us to two further questions: why do such strategic errors almost inevitably stymie our usual dealings with complexity, and what do we need to avoid? Because even the causes of error are in many respects themselves only symptoms; no one, after all, deliberately misses the target, ignores side-effects, or consciously oversteers. Even authoritarian behaviour is not practised as an end in itself. An 'uncybernetic' approach basically just does not work in connection with the system concerned and its self-steering mechanisms. In fact, it usually operates against it – and not just in relation to the system as a whole;

also (indeed, above all) in relation to any feedback controls and their stabilising function. Mere ignorance, disregard, or destruction of the feedback controls operating within the system inevitably account for several of the errors we are talking about. On the other hand, as we shall see later on, there is little chance of even the most interesting strategies escaping Dörner's 'logic of failure' without a great deal of trouble. The answer to the question of why these errors almost inevitably occur in connection with our customary approach to complex systems probably lies in three main areas: firstly, in our habit of considering parts of a system separately and consequently overlooking feedback loops and other regulatory mechanisms; secondly in our tendency, when we do encounter them, to dismiss them as far as possible and establish existing management values; thirdly, in our excessively short planning horizons, which do not encompass such repercussions.

Unpicking reality

To begin with, there is this artificial unpicking of reality, dividing it up into separate subject areas, faculties, and departments, together with a shortcoming in our education that we have already mentioned, whereby 'interconnected thinking' is accorded no sort of priority. This is why my own institute, the 'Frederic Vester Study Group for Biology and the Environment Ltd.' [*Studiengruppe für Biologie und Umwelt Frederic Vester GmbH*] has for many years paid particular attention to the way in which we think and learn things. Against this sort of educational background and in the light of the factual knowledge demanded by the subject catalogue, it is hard for discriminating teachers to impart an understanding of systems. Glance at any school timetable and you will see the world presented as a hotchpotch of separate elements: economics, transport, jurisprudence, administration, waste disposal, geometry, and so on and so forth. The result is that our brains turn into pure 'sorting offices', already separated (as I say above) into distinct subject areas, faculties, and departments. We never experience the world for what it is: one vast fabric in which all these elements are bound together by often powerful interactions.

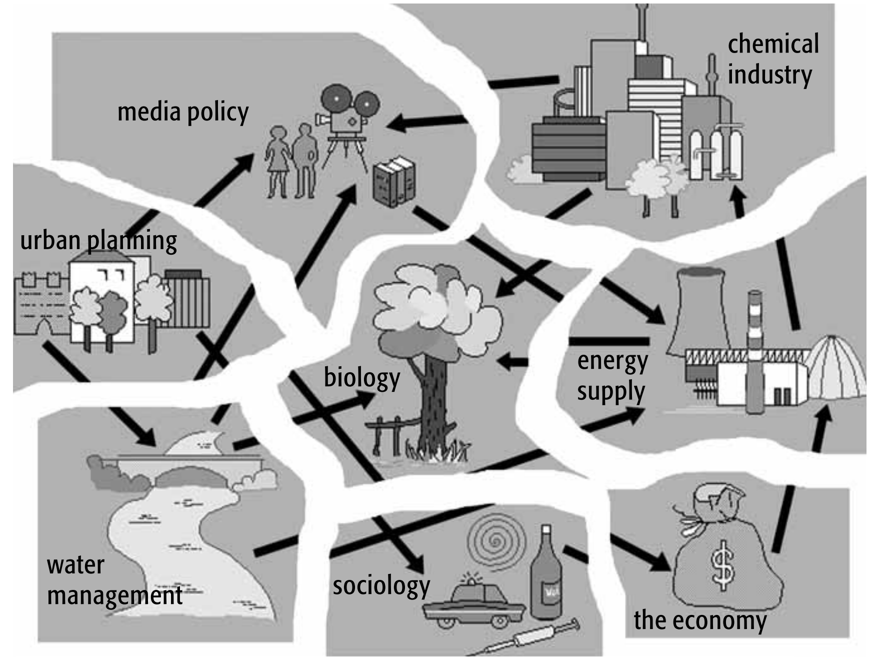


fig. 3: **A fractured network.** We are used to describing individual things in neat compartments, separated by the disciplines that govern them and the areas of life to which they relate; we are not used to describing the links that actually connect them.

Consequently, in later life we bring our decisions to bear on a system with whose every element we are familiar, even studying them to excess, but of whose interconnections we are unaware. The reason is that, like the black arrows in fig. 3, they have been severed. No heed is paid to the interconnections because the subject disciplines override them, and that is why they get no mention in our lecture-rooms and research facilities. But that also means that reality as it is gets no mention there, and expert reports drawn up in this fashion pass reality by, never finding out when and why our interventions possibly break up vital regulatory mechanisms or trigger self-reinforcing feedback loops, simply not discovering where and for what reason we bump into unexpected limits or fail in our plans.

And here we touch on the second reason underlying those intellectual errors: our lack of cybernetic understanding. The fact is, the ignorance so widely encountered nowadays regarding cybernetic control and regulation processes is a direct consequence of the way reality is fragmented into subject areas. The interconnectedness of things, together with the associated cybernetics, falls not so much between stools as between academic chairs; feedback loops go unrecognised. Even so far as division into fields of managerial responsibility is concerned, we see our environment (that is to say, our water, soil, heat, light, plants, animals, insects, and micro-organisms) and indeed ourselves (with our cities and factories, our products and waste products) as a collection of individual components, sharply divided into sectors and authorities; we fail to recognise that every habitat, every living-space, looked at as a whole, is a complex system, an organism in its own right. Part of the reason is of course that the effects of that interconnectedness are largely non-linear in nature; they possess threshold values or incorporate time-delays, which mean that they escape direct observation. But above all it stems from the fact that, unlike things, they are invisible.

Those invisible threads are real

The fact is, they do unquestionably exist, those invisible threads. It is through their interaction that life in nature has for millions of years run on with almost incredible perfection while yet exhibiting huge flexibility and robustness. So for me, as a molecular biologist who had already spent much time studying cybernetic processes in living organisms, it was enormously interesting to look into the principles of organisation according to which the individual elements in major natural systems (an ecosystem, for instance) or artificial systems (a company, a city) are linked together. How far does the way in which they regulate one another, sometimes switching one another off or developing further in the course of evolution – how far does that resemble what happens inside living systems? What emerged from my investigations into a wide variety of systems was that a mere handful of cybernetic rules govern both the creation of that interplay and its continuance. I shall be discussing these in detail in subsequent chapters. One of them (the chief among them) is the principle of self-regulation. And since this principle

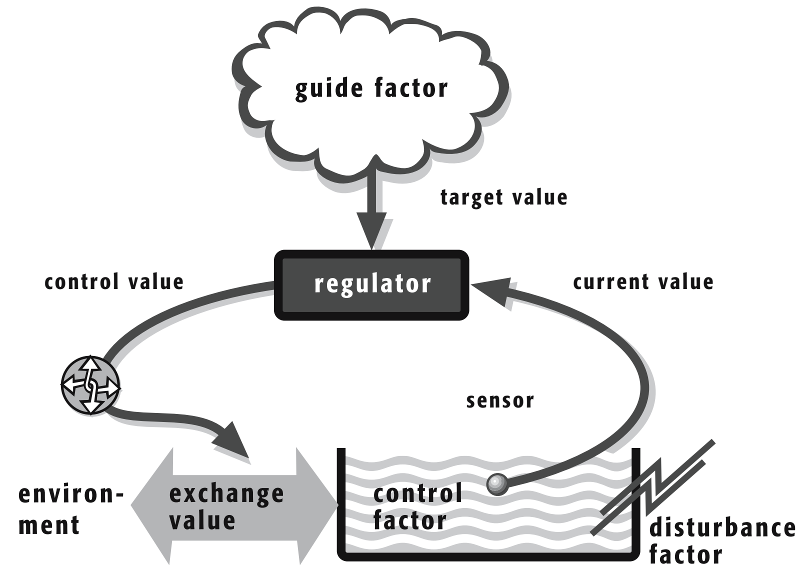


fig. 4: **Classic feedback control loop using current cybernetic terminology**

stands in a peculiar relationship to our errors in dealing with complexity, since through lack of cybernetic knowledge it is violated in a variety of ways, I want to say a few things about it here.

We have seen how several of the said errors can be explained simply in terms of our ignorance, disregard, and destruction of the feedback controls operating within the system. So a strategic approach will no longer invest in solving individual problems by means of isolated interventions but seek to exploit the cybernetics of the system. However, without an understanding of cybernetics it is all too easy, by adopting short-term measures, to break up existing feedback controls rather than harness their often stabilising function, thus dispensing with the help of those brilliant regulatory mechanisms that have kept life going on Earth for millions of years. What, then, is so special about such cybernetic controls?

Basically, what you have here is a very simple mechanism. The principle of the feedback loop enables a system to intercept disruptive influences coming from outside and attacking a sensitive part of the system (its regulatory factors, say) and compensate for or even incorporate such disruption. Self-regulation means that the ideal values of natural systems (the balance between predators and prey, for instance, or the water level in a river system, or the concentration of a hormone in the blood) are automatically held within limits tolerable to the system by means of what is called a 'negative feedback loop', using sensors, regulators, and final control elements. This makes the system error-friendly, robust in the face of disruption, and immune against fluctuations in its environment.

Charles Perrow, in his book *Normal Accidents. Living with High-Risk Technologies* (1984), gives a very precise description of the lack of 'error-friendliness' shown by systems. Nearly all the accidents and disasters he analyses happened in spite of if not because of a lot of safety technology. The book cites Murphy's Law: Anything that can go wrong will go wrong. Actually, there are three 'Murphy's Laws'. The second is: Even what can't go wrong will go wrong at some time or another. And the third (approaching the higher cybernetics, this one) says: Even if something that really should go wrong turns out not to have gone wrong, you'll find that things would be better if it had. This is true, for example, of a series of projects in connection with which we are glad today that they never materialised.

Such experiences long ago shattered the belief of many insurance companies that risk could be reduced by more checking and that errors might be completely eliminated by redundant (i.e. dual and even triple) safety arrangements. Basically, this approach leads in the end to an over-use of technology, which only creates fresh sources of error.

On the other hand the principle of feedback control (which has a great deal to do not only with 'fuzzy logic', as the mathematics of imprecision is called, but also with certain Far-Eastern self-defence techniques such as judo and ju-jitsu) is far superior to such deterministic technologies for the very reason that it does not eliminate disruptions but builds them into the course of events and in many cases even exploits them.

Instead of taking advantage of this property, we (unlike nature) often tend, when we encounter what for us is a 'foreign' mechanism, to remove such self-regulation, interrupting the corresponding feedback loop. This gives rise among other things to false goals – to attacking the disruptive influence directly, for instance (costly symptom-bashing rather than the cheaper course of tackling root causes). We are also fond of eliminating the relevant control (corruption) or paralysing it (red tape). In other instances we break into the feedback loop at the point where the final control operates and prevent it from functioning automatically; we do this by creating debts, operating with state subsidies, and introducing lobbyism and conspiratorial price talks (to circumvent monopoly legislation). Or we ignore the information provided by the sensors (policy of appeasement) – in connection with the Chernobyl disaster, for instance, or radioactive contamination from shipments of atomic waste, or mad-cow disease, or the warnings of ecologists about further deforestation and alternative land use along the Yangtse River, or by disregarding known sources of error in Germany's ICE trains, the dangerous state of Concorde's tyres, the predictable avalanches and landslides in the Alps, or what are now regarded as side effects of genetically modified crops. The sensor picks up a potential snag, so it is ignored.

But even where feedback controls are left intact, abortive development can sometimes occur, and this may affect the control system itself. For instance, we frequently neglect to adapt targets to new management factors, sticking instead to tried and tested procedures or technologies. Yet just this kind of ongoing dynamic adaptation of our own systems and their targets to altered situations is more important today than it has ever been. Even within the biosphere, which is constantly evolving, targets are not set in stone but arise out of the current systemic situation. The steersman is always part of the system – and is in turn steered by the system. Unlike the cybernetics of control engineering or ordinary economic cybernetics, this way you get a kind of hierarchy of feedback, which is a typical feature of biocybernetics. It is this interlinking of a maze of feedback loops that gives living systems their tolerance of error. Errors can occur without (as so often happens in major technological contexts) bringing the whole system down with them.

Yet our general ignorance of the role of feedback loops and the importance of putting them in the driving-seat, so to speak, often leads to our making the mistake of prescribing the targets ourselves. A typical instance of this is our sixth error, namely the tendency to authoritarian behaviour. Echoing a well-known Chinese stratagem, Dörner says in this connection, 'For complex systems, the most effective approach is not to swim against the current but to swim with it, making changes as you go.' In other words, involving those concerned (and not just opponents of a project – supporters, too) in the very earliest stages of studying a system or introducing a course of action is an essential prerequisite for the kind of moderation capable of attracting a consensus. Such an approach, using the dialogue process of the Sensitivity Model (our toolkit for recording and assessing the 'sensitivity' of a complex system) will be illustrated in the practical section of this book. Answers that arise out of an understanding of the system will find the readiest acceptance. Most politicians and entrepreneurs are still a long way from being able to conduct this kind of two-way communication and debate with the general public. However, sparked off by actual financial losses or major losses of 'face', the view that we need additional help here does occasionally get through even to quite large groups and consultancies.

With the headline in the *Financial Times* following the Shell scandal of the mid-1990s (when the company planned to sink a disused oil platform in the North Sea); 'Brent Spar means that business absolutely must involve public opinion in its environmental planning', such a dialogue was for the first time officially begun. The ISO 14,000 series of standards also lists this demand under the point 'Effects on the general public' as one of six environmental aspects to be considered when companies apply ISO (International Standards Organisation) guidelines. In future, it looks as if fewer and fewer projects will be practicable without consumer consent, and this does indeed demand an unprecedented degree of social and environmental commitment on the part of producers. Here the repercussions will more and more quickly affect those who have not yet developed a sense of the way in which events on our planet influence one another. Seemingly jerked awake by the boycott of its products, Shell soon found itself taking a further blow to its image because of its casual attitude to the destruction of extensive habitats (both human and natural) in Nigeria through an almost medieval exploitation of resources.

New guide factors

At this level, then, new guide factors entered our feedback-control systems a long time ago. In connection with projects in developing countries, where of course we as planners are always outsiders in relation to the complex system in place there and lack the empirical intuition of the inhabitants, we are peculiarly at risk (as Dörner has pointed out and practice confirms) of bringing about, as a result of our interventions, the very opposite of what we intended. As BASF cybernetician Eduard Schmäing once expressed it, logically planning crisis committees in particular are often overstretched when they try to improve the critical situation of an interconnected system. When outsiders intervene in a system, because its links have not been understood that system will behave in a counter-intuitive manner; action taken does not produce the result that might 'logically' have been expected or that previous experience of the system suggested.

Probably, however, that result also accounts for our reservations about exploiting feedback loops. We would rather disregard them than place faith on their cybernetics. The fact is, if we take the latter course we feel threatened in terms of our freedom to decide. We do not like things controlling themselves without our having anything to do with it. In our Promethean thinking, we want to be in the driving-seat. It upsets us and hurts our pride that, in a complex system, something should follow its own plan and not ours.

We are quite wrong about this. We need to remember that the reaction of a living creature to changes in the pattern of its environment is usually instinctive – cybernetic, one might say. The mechanism of adapting our 'targets' to fresh situations is indeed among the most fundamental functions in all of biology. If we suppress these instinctively felt impulses (and compartmentalised planning almost forces us to do so), we ought not to be surprised that our breaking of control loops leads to unexpected feedback effects from the system as a whole. Such effects often emerge far into the future – yet they do so the more drastically for the delay. Our blindness to this 'higher feedback' is essentially to blame for the fact that no one is any longer responsible for the whole picture (that is to say, for how the parts interact) since reality (which in any event our brains perceive only

imperfectly) is something we apprehend in little boxes, broken down into its individual components, each ostensibly independent of all the rest. Yet nowadays more and more groups of people are becoming aware of this lack. And when even the chief economist of Deutsche Bank, Norbert Walter, argues for a higher ecotax, having recognised that this will have less of a braking effect than taxing earnings, there is every cause for hope.
Nevertheless, what still haunts the minds of most of our politicians and political economists is an objective that I choose to call the acme of non-interconnected thinking. I mean the concentration on a single guide factor, namely gross domestic product (GDP) and the meaningless growth forecasts based thereon (more of this in the following chapters). 'Help!' people tend to say. 'We're only going to have 0.7 per cent growth. But we need at least 2 per cent.' I cannot imagine a more stupid thing to say in the light of the complexity of our economic system and the interactions of human society. The number means nothing, either in terms of jobs (long since uncoupled from economic growth) or in terms of the quality of life of the population; nor does it relate to innovation, flexibility, corporate earnings, or tax yield. Yet growth there must be at all costs, despite the plethora of examples of where rapid growth tips over and leads to ruin. I shall have more to say on this later.
In the next chapter we shall summarise once again the chief points in which our current non-systemic goal-setting, methodology, and strategy differ from the more desirable systemic approach. In the process we shall examine a third main cause of our error-prone behaviour that we have not discussed before: our excessively short planning horizon, which may have been adequate for agricultural civilisations but is now no longer appropriate, with the world's population density about to top the 10 billion mark and in the light of its socio-cultural interconnectedness. If we are to avoid uncontrollable developments, we are going to have to extend our planning horizon to many times the kind of year-on-year budgeting in common use today. However, our ignorance of complex contexts and hence above all of indirect influences is still an obstacle as regards the time-delays implied. As a result, we tend to recognise the adverse effects of our interventions too late. One potentially high-risk error that results has already been mentioned: oversteering, which can cause an entire system to skid out of control.

3 • Non-systemic goal-setting, methodology, and strategy

Non-systemic developments stem from non-interconnected thinking. How we think determines how we decide, and our decisions determine what happens when and how fast – negatively as well as positively; whether we are ushering in meaningful developments or whether we are making mistakes in our dealings with complexity. As we have seen, the parting of the ways comes early on; it starts with the goals we aspire to.

On non-systemic goal-setting

The chief objective in relation to a system must always be to enhance and secure the system's viability. Failure to recognise this will often lead one astray into desperate goal-seeking. Rather than promoting sustainability, stability, and robustness, one will tend to diminish development opportunities. Above all, such virtual guide factors as 'shareholder value' and the like will be wholly irrelevant as regards the viability of a system. Such objectives as company size ('We want to be world class'), speed ('Quicker than the rest'), mechanisation ('One must move with the times'), or rationalisation ('Greater production at all costs'), objectives to which value is attached independently of their relevance to the system, are adopted as targets without any examination.
In the commercial sphere especially, the usual sort of linear thinking to which networks of influence and repercussions are utterly foreign often sees growth as the only real way forward. Consequently, the only development goal such thinking can envisage is sheer size, which means not just mounting consumption (and with it a steady rise in the rate at which resources are used up) but also greater dependence on the market. In addition (and often to equal effect) there are the other criteria mentioned above, to which we have got in the habit of clinging in connection with shaping our environment and dealing with com-

plex systems: ‘more’, ‘quicker’, ‘bigger’, ‘stronger’, ‘greater’. Such goals are deemed a priori worth striving for and therefore also worth investing in. They stand, we believe, for ‘progress’. To them is imputed a value that is not intrinsically theirs. As objectives, most of them are merely ends in themselves; they serve no other purpose.

According to this, progress in the energy sphere would mean that making more energy available would be better than making less available. In reality, however, our practice during the century and a half since the Industrial Revolution (using more and more energy for the same basic functions) represents in essence a retrograde step in evolutionary terms. As such it is incompatible with the laws of the biosphere, where ‘progress’ runs in precisely the opposite direction. In the lengthy succession of species, new ways were always being developed whereby the same tasks could be performed with less energy than before. Sometimes, as in the case of the transition from glycolysis (1 mole of sugar as primary energy supplies 2 moles of ‘power’) to cellular respiration (1 mole of sugar supplies 38 moles of ‘power’), huge leaps were accomplished. The result made the new species less dependent on its environment and food intake and thus gave it an advantage over others; that species would survive and evolve futher. If the human species now breaks out of this natural development there will be consequences. In fact the repercussions of our rising per-capita consumption of energy are already making themselves felt in more and more areas. The motor car, for instance, as currently conceived, whenever it moves an 80 kg person from one place to another also shifts two tonnes of sheet steel; on top of all the environmental pollution it causes, essentially it is transporting itself. By contrast, the bicycle is around 600 times more energy-efficient; at 16 kg, it can transport five times its own weight in commodities. The car, in fact, is not a step forwards in evolutionary terms but a step backwards. The switch to the bicycle is already under way, at least for urban-transport purposes. As a goal, in other words, ‘more energy’ is in the same class as ‘more information’. And as we saw in chapter 1, the growing flood of information resulting from the Internet and the increased storage capacity of modern computers does not make us any better informed – not by a long chalk.

Take another example: the ‘quicker’ criterion. Look at Germany’s ‘Transrapid’, the magnetic levitation railway with its own monorail. The sole argument in favour of it is a top speed of 450 km/h. Quicker is better; that is all the justification required. Yet sober examination shows this up as an irresponsible project. It makes no sense either economically or in transport-policy terms, as a meaningful use of energy. Nor does it make any sense as a demonstration object for export. There is no real likelihood of another country wanting to take it on. The 15 billion marks that it would take to build a Transrapid link between Berlin and Hamburg (with 9 billion going on the rail alone) would undoubtedly be better spent on improving the country’s rail network as a whole.

It is the same with the ‘bigger’ criterion. The significance of the sheer size of a system is all too easily overestimated, particularly since of the six errors discussed in the last chapter not only the first (false description of goal) but also the third (irreversible foregrounding) and sixth (authoritarian behaviour) all encourage alignment in accordance with this criterion. However, the number and size of the units or sub-systems contained in a complex system always possess an optimum level – for the very reason that they do not exist in isolation but all participate in the cybernetic interplay. If the number of units is too small or the units themselves too small, the expense may not be worth it (think of a café with three seats), packing too dear (e.g. if the contents are cheap), or building up an adequate distribution network unjustified (since transport would be too costly). If the optimum is exceeded and the units or their number become too big (with the result that local supply and waste disposal are no longer guaranteed, for example), the cybernetic interplay and hence the system’s ability to survive will be jeopardised. Many monostructures and many instances of giantism, which as prestige items are correspondingly popular with authorities, have no place in a sustainable economy since they violate the fundamental rules of viable systems. They are expensive and accident-prone, they require a disproportionately large input of raw materials, energy, transport, supervision, and control, and they also have a disproportionately high output in terms of environmental pollution, habitat damage, social stress, and waste products. Local symbiotic exchange (one of the basic rules we shall be discussing in chapter 7) is not possible.

Other megastructures torpedo the market economy by exercising monopolies and opening up the possibility of extorting subsidies. They are also far too cumbersome to be able to adapt constantly to technological developments; in fact, they are often already obsolete in production terms. Moreover, they lock up large amounts of capital for a long time and tend to be more expensive than small-scale solutions. But of course they fit splendidly into the plans of totalitarian countries, lending themselves well to central control and enabling such countries to parade the power of the state clearly before their citizens (which is why giantism is particularly common there).

Wherever large monostructures take shape, be it in agriculture or energy, in every case key advantages of the market economy go by the board and people soon find themselves dealing with problems similar to those that plagued the former Eastern bloc. Yet we too have our monostructures. Think of the all-stifling bureaucracy that dictates EU agricultural policy. Another example is the way in which the monopolistic position of the energy-supply companies has for many decades blocked small-scale cooperative solutions, schemes aimed at feeding power back into distribution networks, and others to exploit waste heat from industry. The effect of their doing so has been to cripple promising sales markets for small and medium-sized industrial firms. In the steel industry and in coalmining, uneconomic subsidies have prevented a transformation from taking place and has set what is an already antiquated state of affairs in concrete.

Also based on the 'bigger is better' criterion is the wave of mergers currently sweeping the world. The stated aim is to 'play a leading role', and the way to that is seen as being to form ever-larger agglomerations (M & A as method of problem-solving). Everyone bows down to the same size fetish, although it is by now open knowledge that one in three of these 'jumbo marriages', entered into with such high hopes, runs into the buffers, and of the rest only every fourth one earns good profits. And then, of course, there are the repercussions on employment, on transport, and on market concentration, not to mention the kind of political influence-wielding by business (going as far as blackmail) that the greater power of size makes possible. More and more voices are being raised nowadays against the socio-economic nonsense of the merger craze. E.F. Schumacher's old 'small is beautiful' adage is being adopted by increasing numbers of entrepreneurs as more and more of the disadvantages of large conglomerates are starting to emerge.

The problem of false priorities dictating action often leads, in connection with complex systems, to purely short-term prosperity rather than to any kind of sustainable development. This is because optimising individual components of a system obscures the importance of optimising the viability of the system as a whole; it is short-sighted in the same way as tackling symptoms rather than causes is short-sighted, and like every fracturing of feedback loops it leads ultimately to inefficiency and often to irrevocably abortive developments.

Certainly it is worth bearing in mind that many abortive developments result from non-systemic ideas regarding the goals to be pursued. Those ideas then rapidly forfeit their claim to absolute authority as criteria of progress, and under the general banner of 'enhancing viability' new partial objectives come to represent 'progress', objectives that are sustainable and therefore make sense in evolutionary terms.

On non-systemic methodology

In addition to non-systemic goal-setting, we also find non-systemic methodology. Even where the goal is clearly relevant to the system concerned and is pursued in full understanding of the need for a holistic approach, many mistakes can be made in the methodology applied (again, as a result of the manner of our education); not a few well-intentioned projects fall at this fence.

In the following pages we shall discuss mainly six methodological deficits that make dealing with complexity more difficult. The first is mixing up different levels of a system (superordinate with sub-systems) and hence stages of agglomeration in connection with data-capture that cannot be compared. This leads inevitably to an excess of information. No reduction to essential organisational parameters is made for fear of not capturing everything. But full capture of every single factor is wishful thinking, being conceivable only in connection with closed systems. What often happens under the influence of the resultant flood

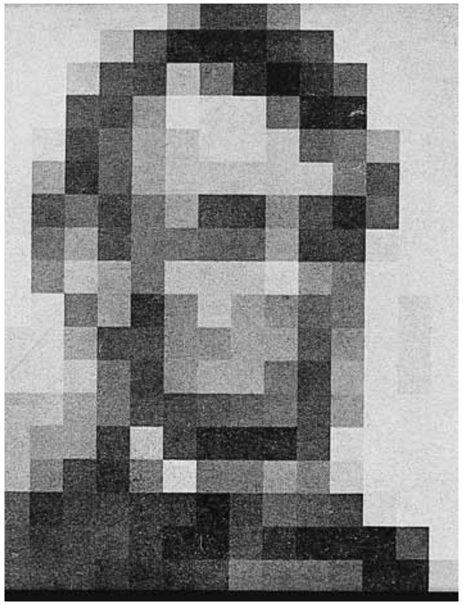


fig. 5: **Computer portrait of Abraham Lincoln**

of data is that the true dimensions of interconnection (direct, indirect, repercussions, time delay) get overlooked, although it is precisely by taking them into account that the amount of data could be reduced.

In my travelling exhibition 'Our World: An Interconnected System', when I want to illustrate 'pattern recognition' I show this computer image (fig. 5). The closer you get to it, the less recognisable it becomes. This experiment has had a firm place in my teaching of interconnected thinking for years now. Seen from close to, the different areas of grey (some light, some dark) do not immediately suggest that this is a picture of a human head. Yet even these few squares will unmistakably reflect the features of American president Abraham Lincoln the moment you move a little distance away, blink hard, or take off your glasses. This is a paradoxical result. While fuzziness leads to pattern recognition, detailed examination of the squares as they are delivers nothing like the same outcome. The number and size of the squares can of course be measured, their degree of greyness can be graded and tables drawn up accordingly. But as regards grasping the system this is the wrong scientific approach – nor is made any less wrong by our pursuing it with such precision. The functions of the components of the system (their 'role' as eye, part of mouth, etc.) will resist identification in this way.

To grasp reality as a whole it is not sufficient to perceive only details. Granted, we shall learn a great deal about the details, but we shall learn nothing about the system as such. We must also connect the details together, which is exactly what happens as soon as the picture becomes unclear and the lines separating the squares disappear. As long as they remain sharply recognisable, our brains work analytically, recording and interpreting the details with the aid of particular parts of the cerebral cortex. Once the picture becomes blurred, the details become less prominent and the relations between them emerge more strongly. What is noticeable is that suddenly quite different groups of brain cells spring into action. Instead of vertical lines and different shades of grey, what are now being recorded are curves and the way areas relate to one another. The brain's pattern-recognition skills are activated, with the result that key systemic connections become recognisable.

In the process, our brains round out the reality they perceive, forming a whole even though parts of that whole are missing. For as soon as we connect together parts of a system, we need only a fraction of the data to pin that system down. In fact, this is one of the core principles of the branch of mathematics known as 'fuzzy logic', which we shall be examining more closely in chapter 10. Here, control of the course of events operates not with isolated bits of data but with interactions between specific areas.

It follows that, for pattern-recognition in planning practice, two things are necessary: data must be stripped down to key components, and those components must be interconnected. This is true not merely of the Lincoln portrait but quite as much of apprehending larger complex systems such as a factory, a company, a municipality, or an ecosystem. Because even major systems have a 'face', and in principle it is possible to recognise that face without falsification by representing the vast number of the components involved by a few key variables – by, as it were, the system's intersections. From the links between those intersections the behaviour of the system is open to interpretation.

Studies of natural ecosystems confirmed this years ago. As soon as you trace the links between what is already a small number of key components of the system, thus (as when considering the Lincoln picture) switching to different neurone fields, just a few 'squares' are indeed all you require to recognise the pattern. Even if they are not measured, the remaining factors are also perceived implicitly, so to speak. Here one thing (data reduction) presupposes the other (interconnection), which incidentally also corresponds to one of the conclusions of synergetics (Hermann Haken).

This brings us to the second weakness of a non-systemic methodology: failure to understand the importance of interdependencies, grasping which is indispensable not only as regards any situational analysis and heeding of side effects but also as regards recognising feedback loops and cycles of control. No study of isolated influence factors, no matter how detailed, is going to produce a usable report. Yet precisely those factors are kept strictly separate in most analyses, with the result that an extra effort is often called for before anything can be learned about the interactions between them. Let us look at the powers of a regional planning authority, for example. Here too, in the field of administration, reality is presented to us in compartmentalised form, as in school and throughout our education. Once again, real systems and their interdependencies are fractured by our habit of establishing separate subject areas.

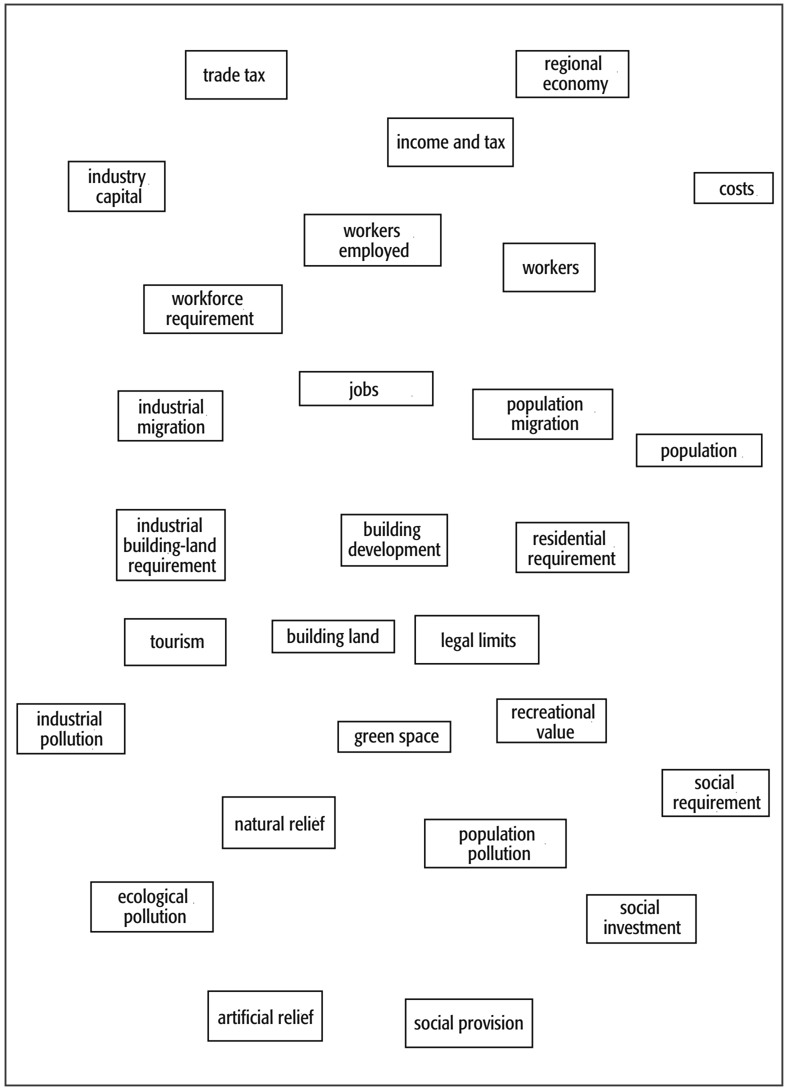
Normally, things are set before us as illustrated in fig. 6a: streets, houses, factories, airports, raw materials, green spaces, jobs, trade tax, and so on. And the signs on the office doors match the categories. Behind each door sits an expert, with the skills that correspond to that particular (Hermann Haken)Hsegment of reality. Consequently, we too think things can be divided up and administered in the same neat way. What we remain unaware of is their cybernetic function, the part they play in the overall system concerned. That role can only be deduced from the links between the parts, never from the individual parts themselves. In one instance, this or that part may act as a regulator; in another as a sensor, a buffer, a final control element, or a reinforcing quantity (to use cybernetic terminology), depending on how it relates to other spheres (see fig. 6b).

As long as we ignore these roles, we shall remain unaware of the actual character of a habitat made up of such parts: its stabilising tendency, its susceptibility to disturbance, its yield balance, its external and internal dependence, how its feedback control systems interconnect, or its degree of diversity. Last but not least, the true opportunities and risks will also be concealed from us in this way. Without understanding the relevant network, we have no means of knowing (in connection with planning a road, for example, or an urban quarter, or an industrial estate) when and where we are fracturing control cycles or triggering self-amplifying feedback loops, where and why our wholly well-meant interventions in the healthcare, social, or economic spheres will hit unexpected limits, or whether, following a brief boom, our plan will run into the ground. While we remain unaware of the network, there is little point in our investigating individual areas, no matter how much data we gather. As regards dealing with complexity, in this case too we shall have adopted the wrong scientific method.

However, a practical approach to capturing systems calls for more than tracing interconnections and reducing data. Even if interdependencies are taken into account, a one-sided and hence false picture may emerge if (and this is the third methodological deficit) we do not grasp the essential components or levels of consideration of a system. We should fail to recognise President Lincoln through the fuzziness if the forehead, an eye, or part of the mouth was missing. What we need to know is: which areas and criteria are indispensable for a system to be described?

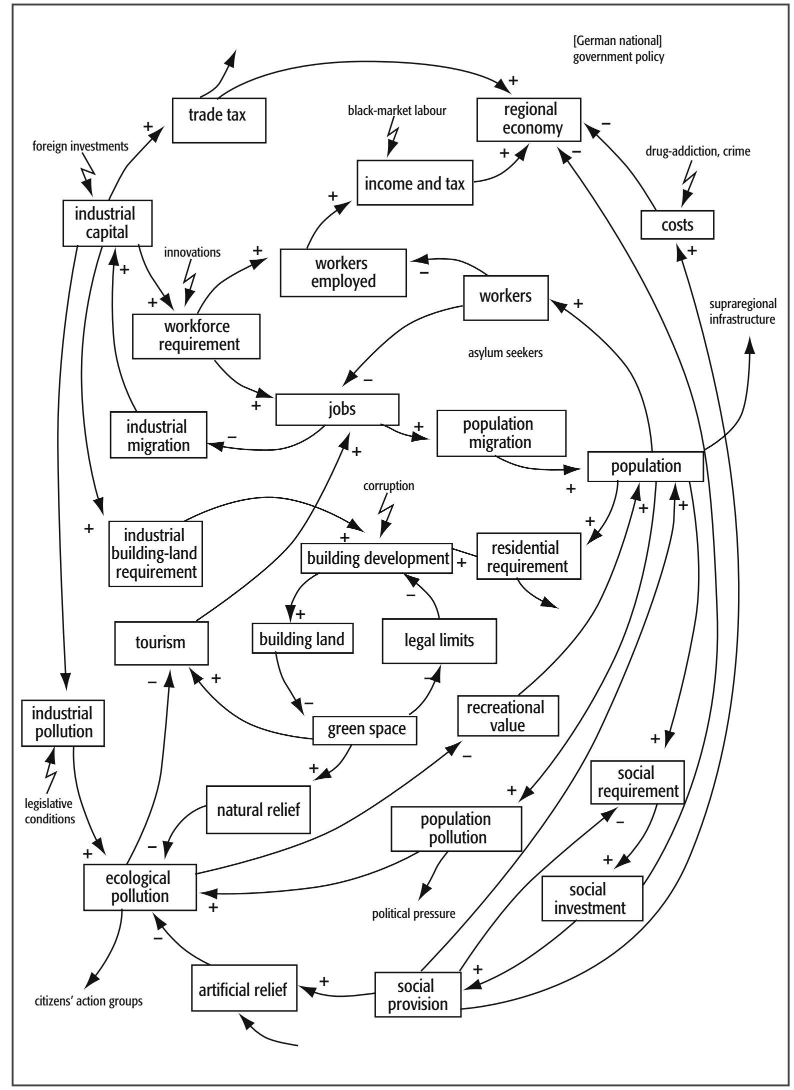
Another reason for an incomplete or distorted description of a system stems from a fourth methodological deficit, as a result of which any intervention in a system may turn into a fiasco, particularly if the deficit has already affected the planning stage. When a system is captured, one thing is often left out of account, and that is how essential it is to include what we have referred to as 'soft' data: consent, attractiveness, dissatisfaction, quality of life, motivation, and so on. Qualitative components of this kind have the same status as regards influencing how the system behaves as do 'hard' factors, which is why in the practical part of this book we shall deal thoroughly with their methodological incorporation in a systemic model. The fact is, if they are not allowed for, any description of a situation is going to produce a false picture; the analysis of the system will be unusable and anything it says irrelevant. The system's inherent behaviour, for which interconnectedness with 'soft' factors is often crucial, is left out of account and will, as a result, produce unexpectedly counter-intuitive reactions.

A fifth unsuitable approach also tends to creep in at the planning stage. Dictated by precision and backed up by modern, centralised computer programs, all the components of a system will be fine-tuned to fit one another as exactly as possible without any play or buffer zones being built in, just as if it was a closed system in which disruption from outside cannot occur. The idea of integrating such disruption, as suggested by our feedback-control model, simply cannot arise in such a case because precise planning (rather than fuzzy logic) demands exclusion of error rather than error-friendliness. If you then add false goal-setting as well, as with today's railway planners, who set their sights on cutting five min-



figs. 6a and 6b: (*above*) **List of subject-areas for regional planning; (right) including effect structure and outside influences**

utes off a four-hour journey but calculate inadequate cycle times, leaving no play in the system, permanent delays are of course programmed in. Instead of five minutes coming off the journey time an hour goes on,



since the connection is missed. The upshot: reliability and image both take hits, customers are lost, and time and money go down the drain. In this case false goal-setting (shorter journey times) affects methodology (over-exact planning) and hence also strategy (reaching the destination with even greater precision). As a result (and this is the case in many

other spheres as well), a failure of regimentation will often be combated with even greater regimentation.
Often matters proceed quite as counter-productively in the construction industry. Here too, flexible coordination of operations would achieve far more than the usual meticulous planning, where even the slightest disruption (never avoidable) sets off a chain reaction leading to massive delays and soaring costs. Procedures such as the K.O.P.F. system developed by Heinz Grote (Kybernetische Organisation Planung und Führung or 'Cybernetic Organisation Planning and Management'), based on the biocybernetic systems approach, are different: they create buffer zones and in this way save both time and money. Introducing a 'second time dimension' into the controlling process, with a corresponding early-warning mechanism, produces flexible opportunities for compensation that absorb disruption without boosting costs. A site office that, eschewing the usual kind of project-management process, operates on such assumptions will not, Grote tells us, be saddled with 'a clockwork collaboration of all involved, where each special request and each deviation has the same effect as throwing sand into machinery; such a site office will have a model of desired futures that incorporates so much variety as to enable it to cope not only with all the special requests and extra demands but also with major unexpected interruptions'.
Among the most common non-systemic methods that are frequently to blame for irreversible placing of accents, oversteering, and not least false goal-setting is the method of projection or extrapolation. Except for a limited time-horizon (and always in connection with a specific system), this is wholly unsuited to forecasting the behaviour of complex systems. Planning by projection can lead only to the gravest abortive developments. In view of its far-reaching significance and unfortunately almost unstoppable popularity, I shall be dealing with this sixth methodological weakness separately in the last chapter of this section.

On non-systemic strategy

Our third area of problems is the habit of clinging to inadequate strategies. We continue to direct projects as if they were isolated interventions, quite without regard to their systemic context. Since no heed is paid to interconnections, the systemic structure of our habitats has changed so much from year to year that once-viable systems have increasingly become chronically sick, and it is only by our spending more and more on 'care' (and no longer through a living regime of self-regulation) that they can be kept from breaking down.
Despite the disastrous repercussions of this way of running things on our environment and on ourselves, many of our decision-makers still think they can get away with a strategy focused on individual objectives and individual problems. Indeed, where everything is going well they feel they should go on striving for the same old targets as hitherto. In failing to recognise the systemic nature of the difficulties they face, not just managers but experts too refuse to let go of the Utopian dream that the economic, social, and ecological damage done by the technological developments of the industrial age can be undone with the aid of yet more technology and that any setbacks (e.g. in energy supply, air and water management, or soil fertility) can be remedied by means of further technological and energy input of an appropriate kind.
Such remedies, which usually take even less account of the foregoing interactions than the original intervention itself, are not only expensive (the 'accident and emergency' principle!); they often entail further consequential losses and dependencies in so far as negative repercussions are intensified and funds removed for preventive measures that would make far more sense. The same is true of those ever-popular measures to protect and repair the environment: by merely overlaying one non-cybernetic technology with another, they allow things to go on as before.
Unlike with a machine, where something wrong (a sheered bolt, say) can be fixed on the spot, in the case of an open, complex system this kind of spare-parts mentality leads only to further, follow-up repairs. As in connection with treating symptoms in medicine, it breaks down self-regulating elements – and that can mean galloping expenditure and eventual collapse.
A meaningful systemic management regime will therefore not try to make one repair after another, wherever damage occurs (continually limping along after events, so to speak) but by installing system-oriented planning and controls set a course for a different situation, a systemic

situation in which there is less chance of that sort of damage occurring. In business, this means not simply planning a specific project but also (and at the same time) looking at that project's primary environment (how did it come about, who is in favour and who against, where is the finance coming from and why, what side effects will it produce, and what will it do to employees and their motivation?). In the ecological context, that kind of management will lead automatically not to costly end-of-pipe technology but to prophylactic protection of the environment that is not only not costly but (as numerous examples now show) on the contrary highly profitable.

Just because, in connection with building and repairing machines or producing finished goods, linear thinking still enjoys and will go on enjoying huge success and has therefore, particularly in periods of growth (in which complex machines behave like machines), also been very successful economically for decades past, it does not of course follow that this positive experience means that the linear, constructivist strategy must continue to work. The truth is, it is simply not appropriate in dealing with complex systems.

As regards non-systemic strategies, many examples can be cited from a wide variety of fields. I want to pick out just three spheres that strike me as particularly glaring in this connection: the whole problem of transport, the water situation, and employment policy.

In most concepts for reducing traffic load we find not only symptom-bashing but also false goal-setting; at the same time, because of a failure to take account of side effects we also find irreversible foregrounding in strategic terms. One result of this is that solutions for managing traffic are seen not so much in avoiding unnecessary traffic movements, in new logistical structures, or in making rail more attractive; rather, they are seen in the extremely costly installation of a giant network of ubiquitous traffic-guidance systems to make car travel easier. Yet this is not like using IT in such areas as teleworking, online shopping, or video conferencing. Computerised control systems would not replace actual traffic; they would simply make it more attractive – which would of course be entirely counter-productive. All this is doing is pushing the threshold of traffic infarction a little farther away. It does nothing to relieve the basic problem; in fact, it makes it worse. The whole strategy is one of giving

in to pressure of traffic; it is theoretical road-building, if you like, such as will only attract more traffic until, once again, 'things can't go on like this'. This way, total mobility will ultimately lead to no mobility at all.

But such examples of a non-interconnected approach having counter-productive side effects occur in other areas than transport; they occur in connection with water management, too. The water situation on our planet is becoming increasingly critical, despite that fact that a great deal of money is being thrown at it and much enthusiasm and many good intentions are being devoted to it. A number of regions that were still fertile a few decades ago are already under acute threat of water shortage. Military clashes over water distribution are no longer out of the question. So what is to be done? Since our knowledge and technological powers are never likely to be up to bringing about a sensible global distribution of water, the vast surplus of that element in the Amazon basin, for example, will be of no more use to our steel industry than all the ice in Antarctica will help the Sahara. It follows that humanity should be thinking on a global scale about systemically sustainable methods of delivering water at local level, i.e. by controlling the ground/air water cycle locally in our favour (as I have already set out in a number of books). The fact is, with a cycle you cannot simply extract at one point without inputting at another, be it on a small scale or on a large one. Yet even this simple cybernetic recognition seems to be missing from many projects, not to mention any analysis of side effects.

As a result, the combined effect of dam-building, river-straightening, energy supply, waste-heat emissions, changing of natural vegetation, draining of swamps, exploitation of groundwater reserves, and inefficient agricultural irrigation, plus short-term use, have altered water resources and our planet's thermal balance sheet noticeably to our disadvantage over the past 30 years.

However, instead of getting at the roots of the crisis, which so far as our consumption of resources is concerned would mean starting with industrial development and its obsession with mega-projects and switching to a small-scale mode of production and organisation that would be system-friendly and adapted to the environment (thereby also benefiting from it), again we tackle only symptoms. Instead of harnessing existing control cycles and making them part of our strategy, we

deal with one symptom at a time. That may solve one problem, but (as we have pointed out) it promptly creates two new ones.
In other words, we seem to concentrate on ignoring existing processes of self-regulation such as operate through negative feedback loops. In fact, we fracture them or combat them rather than make use of them to take some of the pressure off our own control functions. Even more dangerously, we often overlook self-reinforcing developments (vicious circles, if you like) that if not curbed will increasingly rock the boat until it sinks. We pay scant heed to them even where our own interventions amplify their effect. We forget all too easily that interventions in complex systems immediately take on a life of their own through the interconnections that those systems represent. They set off chains of cause and effect that can no longer be reversed; the most we can do is compensate for some of the effects.
I want to cite a third example to show why, in the socio-economic sphere, too, a non-systemic approach based on deficient goal-setting and false criteria will inevitable fail and how often, as a result of that failure, any sustainable, long-term improvement of the system concerned will fall by the wayside. That example is Germany's employment policy.
One thing that emerges from an analysis of the network (a section of which is reproduced in fig. 7) of a systemic study of problems associated with the labour market is that, in the context of employment policy, the spurious argument of securing jobs leads to obsolete major technologies and mega-projects receiving funding that, because they are not thought through systemically, run counter to any long-term development of the economy and hence readily become a financial flop.
This is why the ostensible justification for such mega-subsidies, namely the creation of several thousand jobs (the thick dotted arrow to the right) by an investment subsidy of several billion marks for a major project (Eurotunnel, the Eurofighter, Transrapid, nuclear power stations, the fast-breeder reactor, the Concorde fleet), is often not an employment-creation measure at all but basically a gigantic apparatus for destroying jobs. The fact is, the same amount of investment aid could create 20 times as many jobs in the technology sector of SMB or in the services sector so vital to our future – and at lower social cost. A typical example is the Eurofighter, in connection with which spending 15 billion euros

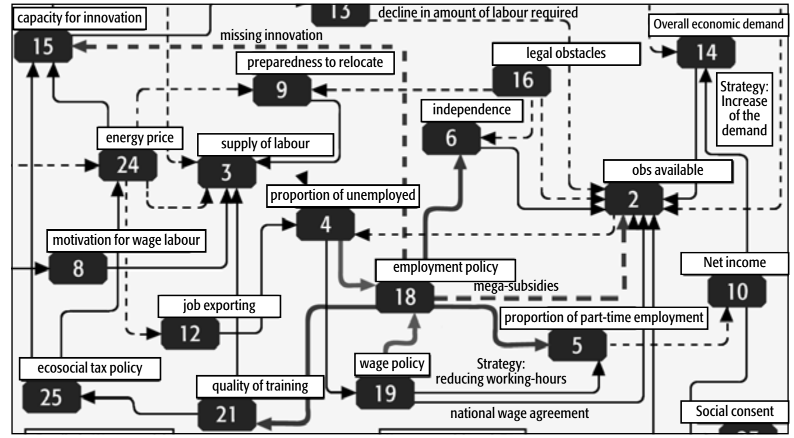


Abb.-7: **Network of a system investigation into labour-market policy using the Sensitivity Model** (section)

of tax money is meant to create 18,000 jobs. Sounds good, on the face of it. However, a brief calculation reveals that each one of those jobs will cost 830,000 euros (rather than costing a fraction of that sum). And this is for a weapons system; it is not, say, for a value-creating business investment. So if money from the tax coffers could be used to create 200,000 jobs but only 18,000 come about, there are grounds for saying that, when something like this occurs, 182,000 job opportunities are in a manner of speaking being destroyed.
Another thing that the systemic model tells us concerns state aid for clapped-out businesses (in fig. 7, the thick dotted arrow pointing to the left). When all's said and done, a large number of such support actions (which politicians like to boast about) simply reward poor management; sick firms are being artificially kept competitive by grants. Some typical examples in Germany have been the backing for Sachsen-Milch, Philipp Holzmann AG, Vulkan-Werft, Max-Hütte, and Schmidt Bank. This not only relieves such businesses of healthy pressure to innovate, enabling them to continue to foist their obsolete products on the market; it also means that they squeeze sound firms out of the relevant sector, firms that receive no subsidies and can therefore, all of a sudden, no longer compete. Insolvencies mount up, and there is no money left to promote jobs that might last and developments that might be important for the future.

Instead of being directed at long-term viability and corresponding prevention, the objectives of most companies are locked from the outset on increasing turnover, maximising profits, seeking mergers, and pursuing other grand aims that, if achieved, are anything but a guarantee against share-price losses and bankruptcies. For instance, in a hectic rush of unprecedented proportions, with the investment banks actively lending a helping hand (not entirely disinterested, that helping hand), wave after wave of mergers has been set in motion, the waves then breaking over the economy so unexpectedly that any kind of sustained thinking about the complex repercussions can only bob along in their wake. For the workforces involved, the consequences are of course direct. But there are also indirect consequences for the economy as a whole, and these can scarcely be predicted.

It is precisely those enterprises that seem bound for success that, when they adopt this kind of strategy of uncontrolled growth, so often run into the ground. All the advantages of the global market economy and of free enterprise can, almost overnight, turn into disaster – from such crashes as Flowtex, Brokat, EM-TV, and Swissair to the biggest scandal of recent days, the wholly criminal collapse of US giant Enron, dealer in power, water, natural gas, chips, and securities, whose annual turnover (by then up to 100 billion dollars) disappeared into thin air early in 2002 and whose stock-market value plunged from 60 billion dollars (which many employees had regarded as a cast-iron pension investment) to zero – unnoticed, if not actually concealed, by the firm of Arthur Andersen, the Group's renowned international auditor. It was a turn of events that, together with the balance-sheet forgeries of Worldcom, Xerox, and others shattered the world's faith in the survival chances of US-style capitalism.

So much for the corporate aspect. On the employee side, the situation with systemic strategies looks little better. The continued existence of jobs is the biggest issue, even if the product of labour is anything but sustainable, giving rise to externalised costs, and the subsidies fought for lead only to production by-passing the market. Here too business bankruptcies are programmed in. By our own actions, we are sawing off the branch we are sitting on.

4 • Paradigms of growth as thing to be aimed at

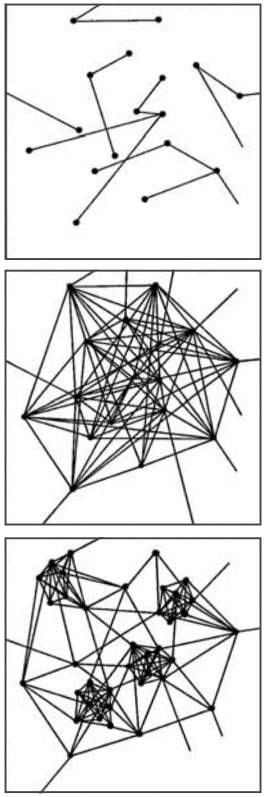
Growth and interconnection

What, as regards the structure of our systems, is the significance of the degree of interconnectedness that has risen so enormously since the Industrial Revolution and the accompanying population explosion? Does it mean simply 'more', 'denser', 'worldwide', or is there a qualitative distinction here, one to be met not in terms of amount alone but with a qualitative difference in terms of organisation?

Growth within a limited space, leading to greater density and hence to increased interconnectedness, does indeed demand a new level of organisation as a strategic response to the resultant stress,. The process can be observed everywhere in the living world, from chaotically migrating unicellular amoebas massing together in a colony of slime moulds to changes in how bird populations communicate – to leaps in the planning horizon for the human species.

The principle of this kind of structural metamorphosis is simply illustrated in the three diagrams of fig. 8. The growth stages portrayed, each with its structures of interconnectedness, as they occur throughout nature, also of course symbolise different stages in our economic development. Thus industry, trade, and technology evolved over a long period on our planet in isolation only, in a scattered fashion (as indicated in fig. 8a); for the time being, they constituted heterogeneous partial systems, independent of one another. Over the last few centuries, like a tissue growing ever faster, these have become interconnected in a single worldwide system. Such growth and heightened interconnectedness occurred in a largely unstructured way, as represented in fig. 8b. An unstructured system cannot survive for long, so a superordinate structure began to emerge, with industrial and technological sub-structures and decentralised economic units, as suggested in fig. 8c. A new phase had started.

However, from about the mid-twentieth century onwards the existing decentralised units are not only forced apart by exponential population



figs. 8a-8c: A non-interconnected system is unstable (8a). As interconnectedness grows, stability grows too, initially, until from a specific degree of interconnectedness onwards it starts to decline again (8b). Unless (that is) sub-structures form, in which case the system remains viable even at a high degree of interconnectedness (8c).

growth; they are also infiltrated by a further technological/industrial growth process, likewise unchecked, running alongside the first, and to some extent (in the financial sphere, for instance) they are already on the way out. We are beginning to move back to the chaotic situation illustrated in the second drawing.

Our future, then, can no longer be about continuing to grow heedlessly and chaotically until we suffocate. Instead, as with all growing systems, we simply must introduce a metamorphosis and develop a new superordinate structure with regional and economic sub-structures. A healthy blend of autarky and dependence, reciprocal feedback and self-regulation is required to revive the downtrodden cybernetic regulation mechanisms and set them in motion once again. Because without them a growing network, left to its own devices, will at some time disintegrate spontaneously. The instabilities now occurring with ever-increasing frequency in the economic and social spheres may in fact be the first negative consequences of our neglect of this law, which clearly permeates the whole living world (to which we and our artificial systems also belong).

So we need to think hard about the true nature of what we are doing. Member of the American House of Representatives and chief of the Oneida Iroquois Bruce Elijah put it like this in a situation report that he gave at a press conference in 1980.

The Earth is an organism in which plants, animals, and people resemble cells. Each tiny entity in that organism has specific tasks to perform, and only if this proceeds in good harmony will the organism live, bloom, and flourish. Technological civilisation man with his compulsive mania for suppressing, reducing, and destroying the natural in order to put giant growths of unnatural things in its place bears a fateful similarity to cancer. Ever since this spiritual sickness has been raging and raging, its consequences spread like metastases over the Earth. Indians have been saying this for more than three hundred years. Check it out. But how is one to explain to a tumour that precisely what it deems a magnificent success actually amounts to suicide!

Such metaphorical wisdom is no longer given to the so-called 'civilised' world. Yet gradually even we are gathering knowledge not intuitively, no, but from scientific sources – knowledge that, once gathered, our intuition too is able to recognise as right. One such source is modern biocybernetics, which deals with the laws governing control and regulation of living systems. It may be that we can tell the 'tumour cells' Bruce Elijah was talking about that in the final analysis they would be much better advised to work with the biosphere as organism than against it.

The findings of biocybernetics also show that a system develops most advantageously in symbiosis with its environment. This will mean that it forms suitable sub-structures and that it in turn becomes part of an over-arching structure, to which it will stand in a reciprocal relationship. Feedback hierarchies of structures and substructures will then arise – a fundamental principle of viable systems that our own body cells already observe. Granted, a system may also grow without difficulty for quite some time even following an unstructured pattern. Cancer cells, too, really thrive at first, growing away merrily (on the maxim: why worry about tomorrow, so long as sales keep rising!) until they become such a burden to the host organism as to impair the functions of the latter and cause it to collapse –bringing the cancer cells down with it.

Optical comparison of the different tissue forms illustrated in figs. 9-11, showing their structures of interconnection, is a startling exercise. At the top (fig. 9) is a healthy piece of intestinal tissue, magnified some 300 times (an intestinal villus or tiny projection with its crypt-like cells).

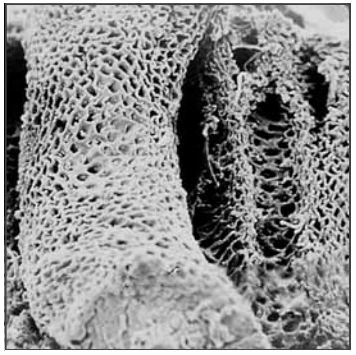


fig. 9: **Surface of mucous membrane of a healthy intestinal villus** (x 300)

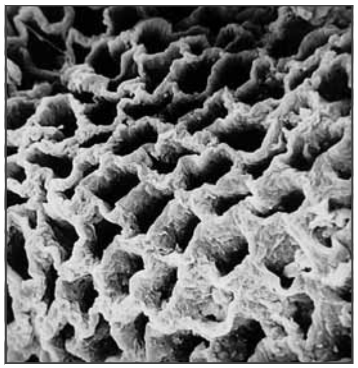


fig. 10: **Regular cellular arrangement** (x 800)

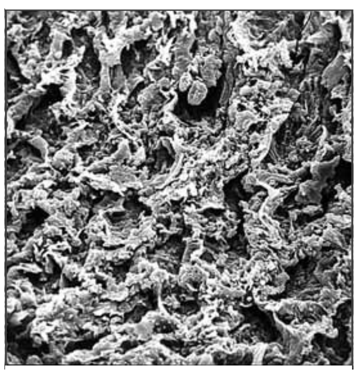


fig. 11: **Ruined mucous-membrane structure of a neighbouring fast-growing large-intestine carcinoma** (x 800)

In the centre (fig.10) we see the same thing magnified 800 times. Each cell is a small factory with many thousands of biomachines and with highly developed logistics. The superordinate structure enabling supply, waste-disposal, and communication to function without a hitch is clearly visible. Below, however (fig. 11), only millimetres away there is an area of cancerous tissue. Basically, this is much livelier; turnover is well up, so to speak; but the ordered structure has obviously collapsed, the former micro-efficiencies of energy-consumption, transport, and logistics have disappeared, leaving an energy-crisis, a build-up of waste, poisoning, and tissue death.

A typical feature of the chaotic structure is poor communication – irrespective of the system's order of size. At the level of the cancer cell you get disturbed intercellular communication, which no longer receives the signals of the organism; at a higher level you get disturbed communication amongst human beings in connection with the collapse of a family, a company, or a community of nations; and ultimately you get a disturbed relationship between human beings and their environment, which is probably the most important interaction of all when it comes to the survival of a species. Here it is the signals of the environment as superordinate system that are no longer grasped intuitively and therefore holistically but are left to measurement devices. Rather than being recognised as a system, its pattern is reduced to a series of numbers, with the result that we

feel less and less at one with that environment. The repercussions associated with the 'spreading cancer' of our economy can therefore also be seen very much in terms of superordinate regulation of the biosphere – as American epidemiologist Jonathan Mann has said of the role of plagues. They could be nature's response to the 'pest mankind' in the sense that, if microbes constituted the immune system of the biosphere, so to speak, they have perhaps chosen this avenue of defence against the uncontrolled proliferation of a parasite.

Growth and density stress

Another systemic law that covers the whole spectrum of living creatures consists in the function of density stress, to which I referred back in 1976 in my first UNESCO study, 'The phenomenon stress' [Phänomen Stress]. The mechanism of density stress ensures that populations that are growing too fast spontaneously begin, from a certain point, drastically to reduce themselves to a lesser and therefore viable density – even by means of disasters, if they cannot change their behaviour themselves.

The fact is, as soon as hitherto isolated single systems (represented in fig. 12 by the symbol of small creatures) rub up against one another to the extent that their private spheres and circles of influence (the rings in

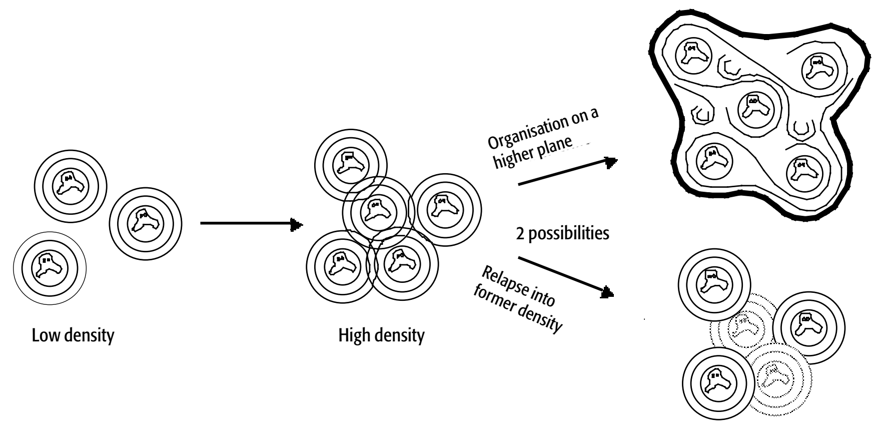


fig. 12: **Diagrammatic representation of the crossing of different density thresholds**

the diagram) overlap, the density-stress function kicks in – ultimately admitting of only two possibilities:
Either this will produce (via a psychosomatic mechanism) heightened aggression, a reduced brood-caring instinct, and sterility, circulation disorders and epidemics, all of which will destroy large parts of the population, bringing it back down by stages to its former density, or alternatively it will compel populations to adopt a different kind of behaviour, assuming a higher organisational form that will enable it to survive even at an increased level of density. Again, it stands to reason that there is a limit to such density at which only the brutal remedy of population reduction will work. Behavioural scientist William Schäfer speaks of the so-called 'critical area', a frontier that a system cannot cross and survive, which is why its only salvation lies in the latter course.
In all likelihood humanity, with a current world population of six billion [1999], is still well short of that point. But it has undoubtedly reached a degree of density where a change of behaviour (and that always, at the same time, means a change of awareness) is imperative. We have seen the example of the amoebas, very simple organisms that above a certain density and the concomitant inadequacy in the food supply increase no further but undergo a radical transformation and by turning into a slime mould (e.g. *dictiostelium discoideum*) find a new form of organisation. This example if no other shows that the law of stress density is clearly something else that corresponds to a basic principle of living species, though its implementation of course differs from species to species.
Moreover, nature has another superordinate mechanism in its arsenal, ready to protect not individual species, perhaps, but the ecosystem as a whole. If a dominant species alters the environment by its great numbers and by the character of its interventions to such an extent that it no longer suits that species, the species dies out. It is an entirely natural process. So there is no need for us to worry about nature in connection with our interventions, but we do need to worry about ourselves, about the species homo sapiens. Many an 'unsuitable' species has been eliminated by nature in this way.
That, presumably, answers our original question; in tackling a higher level of interconnectedness, do we need to make a quantitative leap

only or must we strive instead to give our human society a qualitatively different form of organisation – one corresponding to the structure depicted in fig. 8c?

The hunter/gatherer change of paradigm

A metamorphosis of our forms of planning and organisation is becoming an existential necessity, if only because of the exponential growth in population density that has taken place in recent decades. There is only one question: shall we make it? One event in the history of humankind holds out hope, because here, some 6,000 years ago, a comparable metamorphosis occurred. This was the transition from the economic form of the nomadic hunter/gatherer to that of the settled planter and herdsman. On that occasion an increased population density and the resultant more and more intense overlapping and overuse of territories did in fact force the human race into a radical rethink, making it extend its planning horizon in the direction of greater 'sustainability'.
Such changes of paradigm have occurred repeatedly in human history. However, probably no civilisation ever found itself confronted by a task of this complexity. This time what is at stake is nothing less than the survival of civilisation itself on this planet; no longer is it simply a question, as it was 6,000 years ago, of the hunter/gatherers of the Stone Age becoming planters and herdsmen in order that a few groups might survive in certain circumscribed regions. If those groups were to get by with less living space, they had to switch to a settled economy, one with far fewer inhabitants but a much bigger time horizon before them. Entirely new values became necessary in order to pass from the old day-by-day planning to the new annual planning system, which was 365 times longer: placing seeds in the ground rather than consuming them immediately, letting animals live and even feeding them until they produced young, rather than killing them and eating them straight away. A huge upheaval in thinking suddenly made it more profitable to stay in the same place than wander about. There is something of a parallel, perhaps, with the situation facing us today. Back then, many people living from one day to the next will have found it quite as absurd as many of

us do in the present to draw the next several centuries into our planning horizon.

Nowadays we have reached another density threshold, and this one is coupled with an interconnectedness of systems covering the whole world. Without a change in our old linear way of looking at things we shall be as powerless this time as the hunter/gatherers were then, when their lives were geared only to daily subsistence. At any rate, the continuing exponential growth of humanity will no longer admit the old short-term goal of economic optimisation, which (regardless of the denaturing of our habitat) in essence aims at maximising profit.

Short-term growth rather than sustainability

And yet our decision-makers in politics and the economy (with the possible exception of forestry and life-assurance) are still living in cosy harmony with the annual budgeting of the early agriculturalists and herdsmen, concentrating on short-term solutions to individual problems, shunning long-term strategies, and going out of their way to avoid taking account of the interconnectedness of things. Why? Because they too are afraid of complexity. And so we continue to dispense with any analysis of side effects, identifying individual defects and seeking, with a kind of repair-service mentality, to fix them on the spot without considering the consequences of the repairs we carry out.

Exploding national indebtedness, increasingly critical budgetary deficits, declining purchasing power, an epidemic of bankruptcies and rapidly rising unemployment, mounting environmental problems, a fracturing of social fault-lines, political apathy, and many other indications suggest that in order to overcome an international crisis we have no choice but to make another organisational leap and effect a similar metamorphosis to the one that occurred 6,000 years ago. We are going to need courage. This is about evolutionary management; long-term strategic planning is called for.

However, a major obstacle to a cybernetic approach is precisely this long-term nature of the planning requirement, the fact that it means including longer time spans than we are used to in our annual budgetary planning. With our truncated time horizon we want see results as soon as possible. We simply refuse to get involved if it is a question of steering current developments (the harmful effects of which are in any case not actually felt by most people) in a different direction. We guard against introducing changes (in energy and water consumption, say, or tax legislation) and accepting any corresponding extra expense, the true benefits of which will often be experienced only by the next generation or the next-but-one.

So how are the men and women of the industrial society to be told that they should do something or stop doing something when such action or cessation will bear fruit only in 10 or 20 years' time, when many of them will no longer be around to see it? Cancers, allergies, failed harvests, forest fires, floods, avalanches, and mudslides are all things we know about, certainly, but only as affecting individuals. For the general public (ignoring for the moment the 4 million unemployed and the 30,000 businesses that go under every year) life has never been better. The talk is all of boom times and economic growth; the shops are a paradise, overflowing with goodies. Yet we are paying with uncovered chips. Most people still feel little concern that even reputable calculations agree: ongoing rise in our resource-consumption and in our emissions, besides producing many local repercussions, is not only (like El Niño) shifting remote ocean currents; it may even cause the Gulf Stream to break down, with the result that, despite global warming, a few hundred years from now northern and western Europe could enter a new Ice Age. But never mind: our oil heating still comes on.

The situation makes it difficult for even politicians with insight to get long-term strategies accepted. Decision-makers who lack insight or are blinded by short-term, profit-oriented thinking can very easily block such initiatives with no prospect of any resistance to speak of amongst the populace. Certain branches of industry are known to have taken sides already. Most people resist change; they certainly don't want to be forced into a rethink or made to give up familiar patterns of behaviour. It looks like stalemate: on the one hand, blithe cries of 'Let's go on as we are'; on the other, the fact that in parts of the world the ecological and economic situation is already in a state of collapse and the inevitable repercussions are forcing us to act.

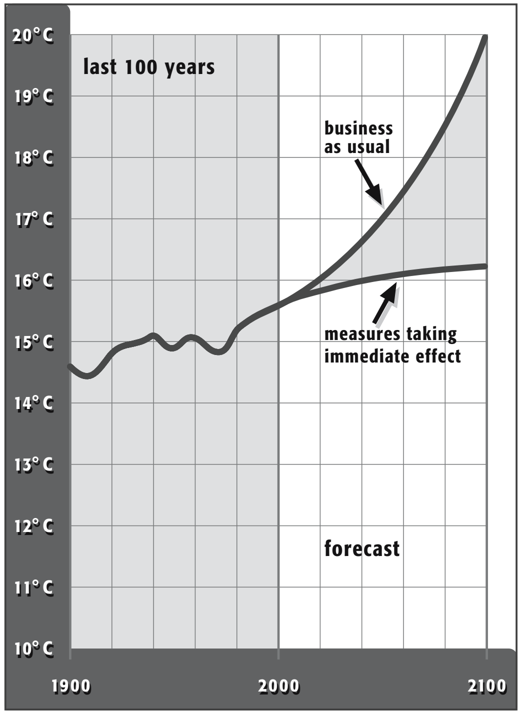


fig. 13: **Course of mean global temperature and forecast of global warming over the next 100 years.** The next climate peaks will show whether there has been a successful change of course and the associated risk of natural disasters has been brought under control (after Munich Re 1999).

Although as an extrapolation from a complex process the graph depicted in fig. 13 may need qualification, it does show, in the way in which it fans out as a long-term 'what-if' forecast, a strong correlation between global warming and all its consequences and our economic approach. While most decision-makers in politics and the economy face this and other reactions of global ecosystems and climate with apathy or despair and are consequently edging us into an increasingly difficult socio-economic situation, in one branch of the economy, as we have seen, the adverse effects of this kind of mismanagement were felt at a relatively early stage. I am talking about the insurance industry and in particular about reinsurance companies, where claims arising out of environmental disasters have multiplied since the 1980s, reinforcing their awareness that this is due not least to our increasing interventions in the balance of nature: to motor traffic, settlement structures, unnatural treatment of field and forest by monocultures and logging, river-straightening, dam-building, accidents to chemical plants, nuclear reactors, oil tankers . . . the list goes on.

Impressed by such links and convinced that the only way to approach these problems is through interconnected thinking, several major insurance companies got together under the name NERIS [*Netzwerk Risiko im Sensitivitätsmodell or Risk Network in the Sensitivity Model*] to conduct what was called a 'risk dialogue' with economists and politicians, a dialogue that has since gone public with demands that we turn away from the growth paradigm and its associated exploitation mentality. A Munich Re strategy paper [Munich Re is a very large reinsurance company based in Munich] also says that growth is certainly not an objective; even less is it a means of solving problems.

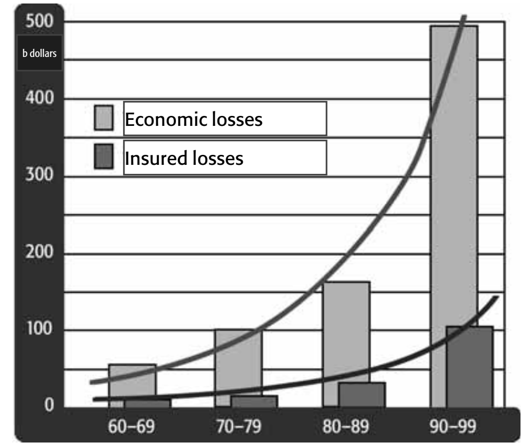


fig. 14: **Environmental disasters since 1980**
(after Munich Re)

The powerful commitment of insurance companies in this regard is very understandable, particularly from various economic viewpoints. A glance at fig. 14 will show how their claims bills for environmental losses has been growing exponentially for years, leading to a drain on reserves of several hundred billion dollars. Purely in consequence of increased storm damage resulting from the greenhouse effect, according to information provided by Munich Re those losses amounted to 17 billion dollars in a single year. We are talking about an entirely different scale here! In 1998 alone (1998 was the warmest year by far since measurements began in 1850), Munich Re recorded an unprecedented 707 major natural disasters causing millions, even billions of marks' worth of damage and calling for supra-regional and in some cases international assistance. According to the calculations of the company's geoscientific research group, compared with the 1960s the number of major disasters was up threefold, losses to local economies were up ninefold, and costs for losses insured were as much as fifteen times greater. A further rise (plus of course a corresponding hike in premiums) can be expected.

Yet the indirect causes of such damage (cars, for instance, and oil central heating, with their contributions to the greenhouse effect and its consequences) are not even involved in third-party liability; instead, the

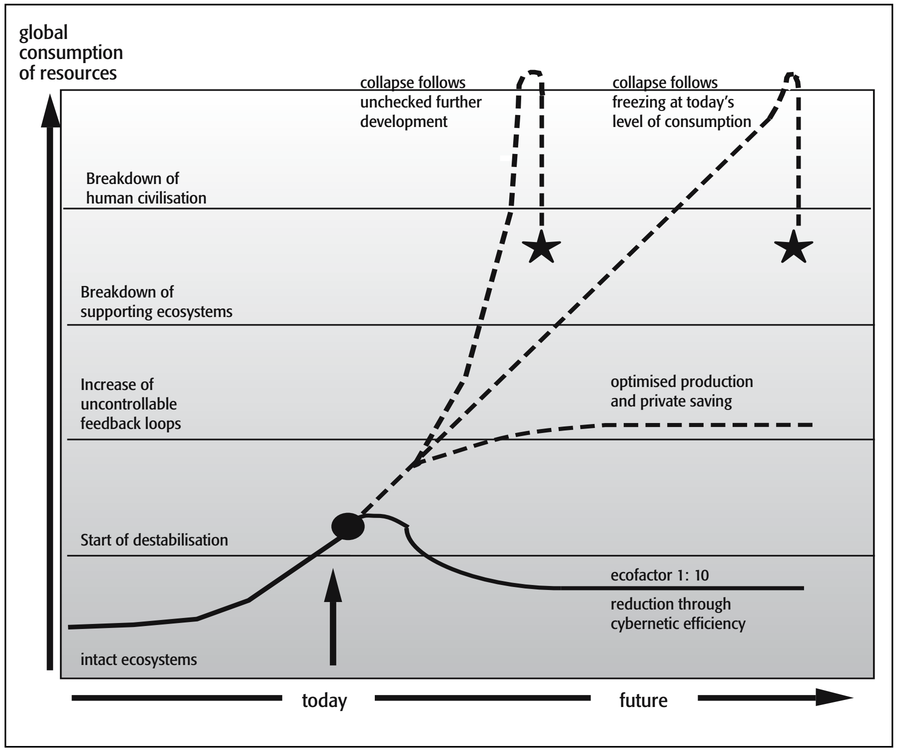


fig. 15: **Economic efficiency for a sustainable future.** To avoid further ecological destabilisation, global material streams must be substantially reduced – in the industrialised countries, by a factor of 10. Countries that take the lead here will be among the leaders of the future (with acknowledgements to Schmidt-Bleek).

costs incurred (between 200 and 600 hundred billions a year, depending on the method of calculation) are externalised, which is to say they are borne by the economy as a whole. There is a lot of argument about putting petrol up by five marks a litre; the fact is, we have been paying this indirectly for years – even people who do not drive.

Securing our existence in the long term will indeed require a short-term reduction of current resource consumption by a factor of 4 but a long-term reduction by a factor of ten! How over time we could achieve this aim even without clipping our prosperity has been addressed by Ernst Ulrich von Weizsäcker among others as well as in a book on the subject by Friedrich Schmidt-Bleek, until recently president of the Wuppertal Climate Institute and founder of the Factor 10 Club. The book is called 'The MIPS Plan' [*Das MIPS-Konzept*], the letters standing for 'material input per service unit' – the cost-benefit ratio, in other words.

Cutting that ratio to one-tenth of its present level is by no means a Utopian goal when you consider that a good 90 per cent of the materials and energy used today are simply wasted. Schmidt-Bleek cites concrete examples to show that an ecologically optimised economy could very easily get by (at no cost to its quality of life) with a fraction of current levels of consumption of raw materials and energy – and a corresponding saving, of course, in financial resources. In transport, those levels could even be reduced to between one-twentieth and one-thirtieth. It would be a first step along the road from a product economy to a knowledge economy that futurologist Matthias Horx talks about.

As regards the strategy of an ecologically optimised economy, this will inevitably mean promoting everything that brings down costs (without affecting benefit) instead of pouring money into the very sectors that seek by hook or by crook to perpetuate the trend of rising expenditure. In a nutshell, what is desirable should be made easier financially, while everything counter-productive in this respect should be made more difficult.

Any subsidisation of developments corresponding to the rising branch of the curve means actually cementing the diseased state; it brings our society closer to collapse and is therefore basically destructive. If we do not swiftly, backed by dynamic circulation-economy legislation and a progressive energy price, move away from our short-sighted economic approach with its fixation on productivity growth and *shareholder value* towards *sustainable development*, we face the threat of dangerously extensive fissures, not only of an economic but also of a social nature.

Rather than continue to pursue projections, rationalise out flexibility, crank up economic growth, and then produce as it were without reference to the market, it would make more sense to get to know the cybernetics of one's own system at last, be this a region or a company, and introduce some improvement. Happily, more and more entrepreneurs now see growth (and have done for a long time) no longer in size terms alone; they also look for growth in internal company values, in structural terms, and in terms of quality of life. This is in fact a qualitative type of growth; it takes place in the information sphere, not in those of materials and energy.

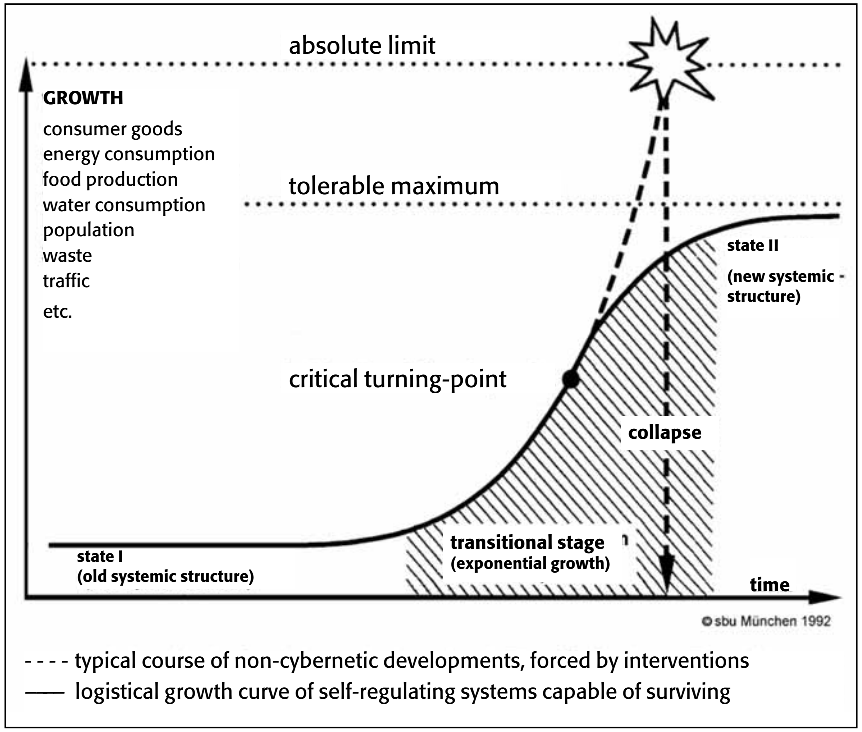


fig. 16: **Exponential growth curve and exceeding of limit**

We ought far more often to contemplate the regularity of the growth curve depicted in fig. 16, the logistical path of which is the same for all living systems, even bacteria. If by means of all manner of tricks the critical feedback point of normal growth regulation is passed, collapse is virtually pre-programmed. The view that growth can be created still dominates the public mind. However, sustainable systemic growth can only emerge from a systemic situation. As the logistical curve shows, all healthy growth is merely a temporary phase, leading to a fresh stable state. Before the next growth spurt, a living system needs a period of internal restructuring. But because during the growth phase everything was so beautifully simple, naturally there is a desire to continue moving inexorably along the dotted curve in our graph.

Yet it would be eminently important, while growing, to pause occasionally and carry out the necessary restructuring, to mature, to undergo a metamorphosis. However, regulating feedback mechanisms, which would in fact make this possible, are ignored, brushed aside, we never pause, instead we take out loans, we operate with dumping prices, and when even that no longer works, we call for public subsidies. At some point we come up against a limit, a point at which it is no longer possible simply to adjust the scales. Suddenly there is overcapacity, the interest burden allows no further investment, and bankruptcy becomes inevitable.

In the field of employment policy, too, you still hear constant arguments for quantitative growth, although in many cases it is precisely through growing productivity that many jobs have been lost or shifted to countries where wages are low. So quantitative growth is no longer a guarantee against unemployment. In fact, growth and job-creation have been uncoupled for 20 years, and we really should have grasped this by now and started looking for a solution to the problem not in yet more growth and deficit spending but in new structures. The old solution patented by John Maynard Keynes stopped working long ago. Nor am I alone here; it is a view shared by others, notably Philippe Séguin and Horst Afheld.

According to Philippe Séguin, President of France's National Assembly and anything but a 'leftie', 'what really ails us is deficient thinking about unemployment', and he concludes that 'what is wrong with models of economic theory is: they pay no heed to today's reality'. It is a view to which Horst Afheld of the Starnberg Research Institute gave particular prominence in a review of Séguin's book, 'Waiting for employment' [*En attendant l'emploi*]. Politicians, Séguin says, should ignore the advice of the 'wise men' of economics, all of whom learned their expertise in the (economic and technological) dusty Stone Age of the 1950s and 1960s; it is economists who must finally start basing their theories on the reality of today if they wish to tackle the problems of today with fresh expertise. In Séguin's opinion, then, the separation of the finance market from labour is among the great evils. Afheld's review says, 'That separation is assuming dramatic proportions. For a long time it has been clear that the world of finance doesn't give a fig about employment. But today we have something worse. The world of finance also cares nothing about the economy. The fall on the New York stock mar-

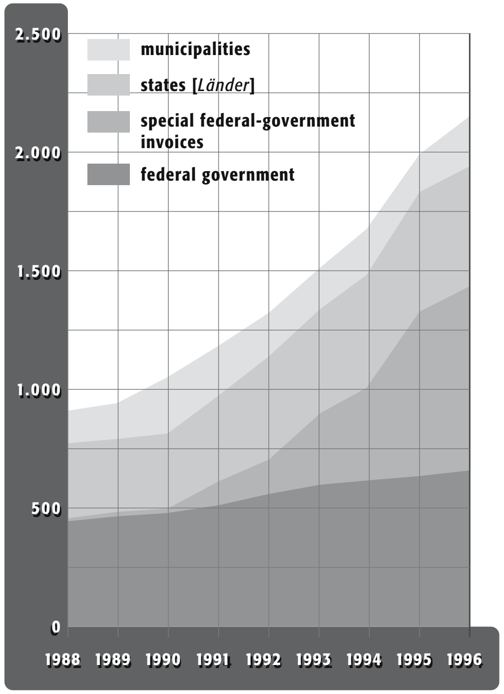


fig. 17: **Public indebtedness in billions of DM** (2001: 2,312 b)

ket that greeted the announcement of lower unemployment figures in the US highlighted the inauguration of this upside-down world.'

All of which is not to say that growth as such should be condemned. The S-shaped logistical growth curve shows that growth is provisionally, in the right circumstances, quite acceptable (indeed, in certain phases of development even necessary), but on one condition: it has to keep to the logistical growth curve. The main thing to guard against is dependence on growth. A company must be able to thrive even without permanent growth. If on the other hand it is so structured as to be dependent on growth or on having, at all costs, to keep marching along the dotted line, collapse is only a matter of time. The same applies with regard to the repercussions of social and economic myopia on the state itself. Glued to the misconception that growth and size are the best way of dealing with problems, national and municipal debts will mount up ever faster. A glance at fig. 17 will show that, in Germany, public indebtedness has more than doubled in eight years. It might have been predicted that real investment would necessarily decline in the process since available resources are increasingly soaked up by the interest burden, yet it does not prevent many politicians from contemplating further financial adventures rather than budgeting with what is left in a way that makes sense. Consequently, a drastic austerity package is now unavoidable. But it would be more acceptable to voters if it hit the rich as well, and if education and social services could be left alone

and subsidies to big business cut instead.

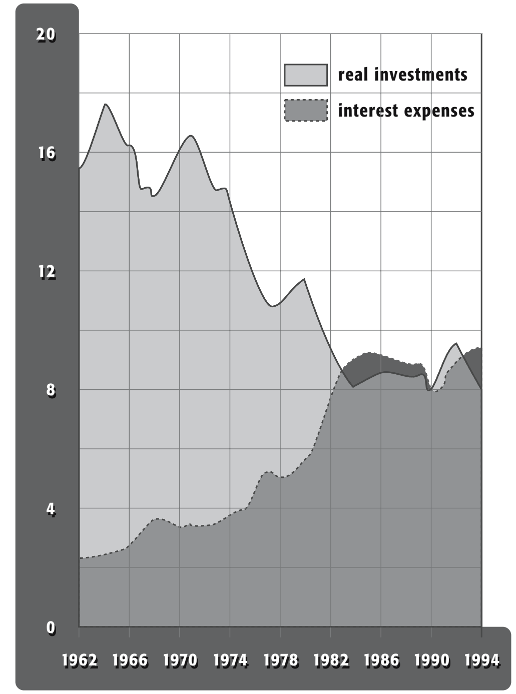


fig. 18: **Interest expenses and real investments as percentage of overall public expenditure, 1962 to 1994** (stayed approximately constant until 2000)

I am not the only one to see the narrow-minded policy of subsidising obsolete branches of industry at the expense of more forward-looking technologies and forms of service as a quite absurd way of going about things. It completely leaves out of account what salutary control opportunities might flow from simply abolishing such subsidies. Such opportunities range from forcing the pace of innovation to encouraging firms to switch quickly to less polluting forms of production or to providing services instead – surely the most interesting alternative in the light of the MIPS concept I mentioned a moment ago. The spectacular recovery of New Zealand as a result of such a radical cure has been an initial shining example of what can be achieved, offering a glimmer of hope that we too can pull ourselves up out of the mire – even if the Asian crisis has once again given the country a bit of a knock. The Taiwanese example also shows that a country without deficit spending and a high level of indebtedness can thrive, creating far more stable conditions in this way. Because of its political status, Taiwan had no access to the International Monetary Fund or the World Bank so was saved from abusing the 'growth loan' drug. Certainly, such examples throw our own strategic deficits into high relief.

5 • The snares laid by projection

As we have seen, there is a great deal of evidence that (on the analogy of the development principle of living systems) a permanent orientation towards growth gets in the way of metamorphosis and innovation. We have also seen that even so-called progress criteria (bigger, faster, further, higher) often turn out to be regressive. For many systems they have made sustainable development impossible. Even technology assessments and tests of environment-friendliness clearly fall short, given the kind of systemic sustainability required. They mean that investment is often poured into developments that, despite detailed expert reports, have no long-term future in a systemic context. Faith in the predictive power of projections is likewise (in addition to the non-systemic methods we have already discussed) responsible for a not inconsiderable share of the wide variety of problems facing us today. So in the following pages I want to look rather more closely at the controversial field of economic forecasts.

We are far too ready to be tempted to look at past experience and extrapolate from it into the future, then to use the outcome as an aid to decision-making. This is because not only are projections quite permissible so far as statistical phenomena are concerned; they can also, in certain circumstances and for specific periods of time, have much to tell us about complex systems. Why? Well, in two particulars complex systems behave like machines: firstly during growth phases and secondly within a short time horizon. In both cases their development can indeed be determined by extrapolation.

Projections of growth phases

On the basis of such experience, however, we wrongly assume that, if deterministic projections lead to correct decisions in periods of growth, they must also work after such phases. We forget that the linear constructivist method is in essence quite unsuitable for controlling a complex system, since apart from the two cases mentioned such a system behaves in a fundamentally acausal way. As soon as interactions with the outside world predominate and limits or thresholds are passed, the behaviour of a system can no longer be predicted using linear cause-and-effect relations. For instance, positive feedback mechanisms may react to the least impact on the system as a whole or on part of it by moving up or down, provoking fluctuation or collapse. Time delays may also conceal a latent start of such developments or the fact that they have been ongoing for some time.

Possibly through ignorance or being caught up in the mistake that earlier positive experiences must continue to hold good, many a top manager has manoeuvred him- or herself into seriously erroneous decisions on the basis of simple projections. In a phase of economic growth, as represented by the steeply rising section of the S-curve back in fig. 16, things were different. During such a phase one knew: last year the company's turnover stood at a certain level; in the current year, it is up by this amount; next year it is pretty likely to reach such-and-such a figure. In a word, one could plan deterministically. In such times, a big firm might be headed by a person with no training whatsoever in systems thinking. Projections worked, and if the experts ever made a mistake an almost automatic growth process would compensate. Some of the top executives who successfully practised this method are still sitting behind big desks and on supervisory boards, surprised that suddenly things have stopped following the usual pattern. With the system behaving acausally, they no longer know what to do, and they produce (often in panic) one wrong decision after another. Hence, possibly, the notorious call for growth, both by politicians and by business, because growth is something of which they have experience. And so the call goes out yet again: try and get there artificially, by buying up other firms, maybe that will take us beyond the crisis point and we can go on as before, moving inexorably up the logistical growth curve. Whereas what they should be doing is adapting their way of thinking to what the situation really requires.

Abortive developments resulting from neglect of systemic laws, mistakes that come about through simply extrapolating from growth phases – examples are legion. To clarify the principle, let me select three areas: tourism, energy, and road traffic.

In the development of tourist areas, projections are mainly to blame for false marketing forecasts and resultant ruinous investment programmes. There is no shortage of cases (in Bavaria, Spain, Gran Canaria, Lanzarote, Austria, Switzerland, or Turkey) in which the construction of new or the expansion of existing tourist areas, once the growth phase was over, soon brought only innumerable consequential burdens. In the Swiss holiday resort of Leukerbad, for instance, the municipality, having overstretched itself in terms of investment, had to sell off all its assets in 1999 (sports arena, underground garage, thermal baths, and community centre) to stave off bankruptcy. Connections that at first glance reveal a linear course, a proportional increase, will often (purely through the advent of new forms of behaviour or perceived values and because of their reciprocal links with the system as a whole) come up against those unseen limits and thresholds as a result of which what began as a smooth development suddenly switches direction and may end up as an unexpected ecological and economic catastrophe.

The mechanism of such abortive projects is always the same. If the X-axis on the following graph (see fig. 19) stands for the accessibility of a particular area and the Y-axis for its attractiveness to tourists (to pick out only two factors among many), for a while attractiveness increases with accessibility; the better the infrastructure, the more people want to go there. Only when the optimum has already been exceeded do the repercussions resulting from rising traffic, disfigurement, noise pollution, and loss of originality come into play. Further road-building to improve accessibility and the construction of larger hotels to make mass tourism possible will only make the situation worse. The attractiveness and hence the image of the place will decline – and that is without terrorism.

In my book Crashtest Mobility I show that the 'improved accessibility = increased attractiveness' ratio based on simple projection holds good

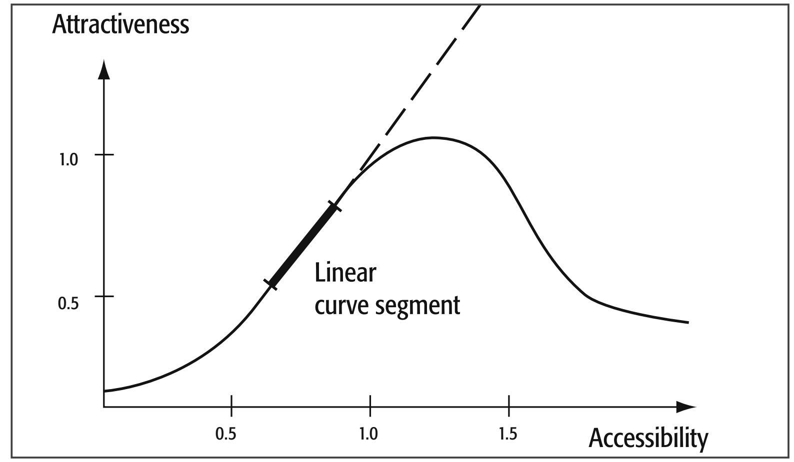


fig. 19: **Attractiveness of a landscape as a result of accessibility**

only for a small section of the curve. It would be fatal to extrapolate from that section and improve accessibility by building more roads, car parks, and helipads in order to increase attractiveness. Yet that is precisely what often happens. In many cases political or economic guidelines and pointers are extracted from observed data movements that are basically only tiny fragments of very much more complicated non-linear curves or even networks of curves, which are only noticed (all eyes are of course on the longed-for rise) when irreversibilities occur and repercussions and threshold values come into play.

Similarly, in many other spheres policy tests that might have made useful strategic indicators ('what-if' prognoses) are replaced by development forecasts. These are frequently misleading, leading to over-capacities, rationalisation where none is needed, or collapse through dependence on growth, when this abruptly turns into recession. The end result is that what are called conservation grants and are used as the method of last resort for saving sick businesses and ancient practices actually shore up the wrong product and hence perpetuate the obsolete state of affairs.

Another typical example of false course-setting by means of deterministic forecasts is the development of energy consumption. Forecasts of future energy requirements that were detached from reality but were

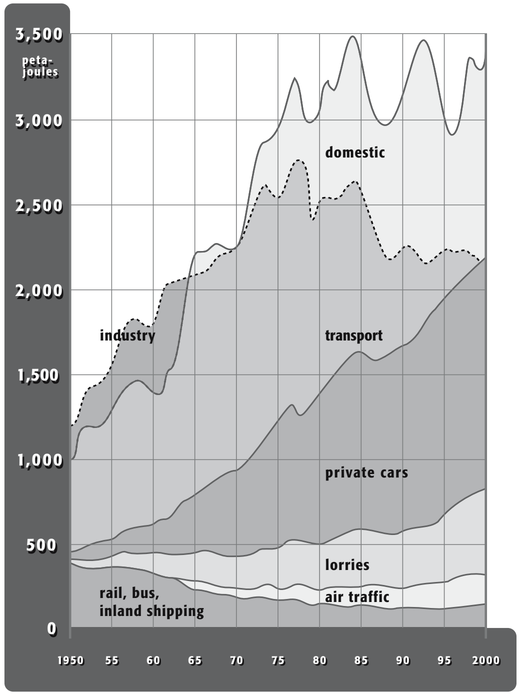


fig. 20: **Energy consumption in West Germany by economic area and mode of transport** (Source: German Institute for Economic Research)

instead arrived at on the basis of linear-causal extrapolation have repeatedly, since the 1960s, turned out to be exaggerated and still get in the way of our constructing a realistic energy economy for the future. Currently in Germany around 25 per cent of available power probably represents over-capacity, with a further 25 per cent of unused capacity resulting from a failure to harness industrial heat. Anyway, given over-capacity in the region of 100,000 MW, abandoning nuclear energy, for instance, would not leave even the tiniest supply gap. I would argue that it is more likely to be the enticement (not to say bamboozlement) of public and politicians by such erroneous forecasts that has led to an ever-increasing appetite for energy and, when all's said and done, led to the world facing a true energy famine at some future date. Bamboozlement on the one hand, ignorance on the other. Because according to the latest reports by geologists, our oil reserves are gradually approaching actual limits. Few new fields are being discovered, whereas consumption (encouraged by dumping-level prices) is growing all the time. Experts predict that from the year 2010 oil prices will explode.

In industry and in private households the signs of the times are increasingly gaining recognition, but transport continues along a growth curve, as comparison of the consumption curves of private households, industry, and transport in Germany between 1950 and 2000 (fig. 20) makes clear.

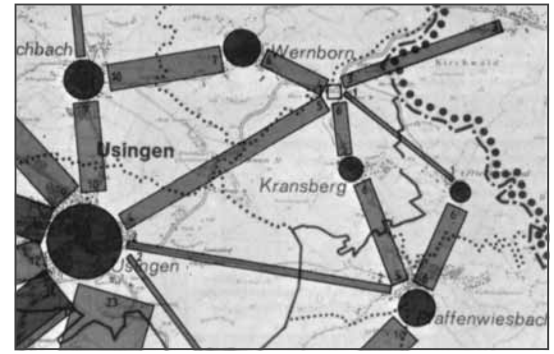


fig. 21: **Transport map of Hessen State Regional Planning Department** (excerpt)

The different way in which the three consumption sectors are developing is closely bound up with the fact that in transport particularly (and, within transport, particularly in the individual sphere), the projections do indeed appear to anticipate reality. The extrapolated development is accepted as given, and from the traffic flows observed the road-widening schemes that will be required in future are calculated. As documented in my books 'Tast exit for the future' [*Ausfahrt Zukunft*] and 'Crashtest Mobility' [*Crashtest Mobilität*] as well as in many of our studies using the Sensitivity Model, with traffic (unlike most other sectors) it is not demand that dictates supply but supply that determines demand. This is why, so far as traffic development is concerned, we are basically trotting along in the rear: each time private traffic is eased, increased traffic results, just as every improvement in public transport (for example, by cutting connection times) prompts a switch from car to train or bus – in some cases a switch of several hundred per cent. So if we want to avoid any further increase of road traffic with its concomitant stress on population and environment, it will not be enough to measure and extrapolate from existing traffic flows and their distribution over competing traffic carriers.

In the usual approach, interconnected thinking extends only to topographical space itself and to numbers relating to traffic occurrence, as illustrated by traffic maps such as the one of which a section is reproduced in fig. 21. How the different flows come about, what makes people travel, what bothers them or others in the process, how this affects farming and retailing – all these things are left out of account. So while our costly censuses measure all the different traffic flows in a catchment area and deduce from them what action needs to be taken, we fail to examine why people travel or what prevents them from using

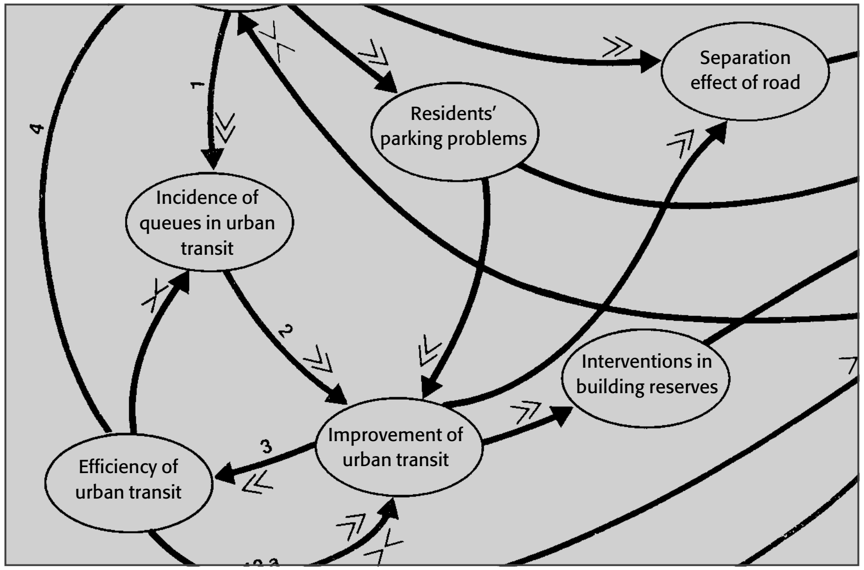


fig. 22: **General Transport Plan of Frankfurt Umlandverband** (excerpt)

other means of transport. Through improved road design and wider carriageways, supply on overloaded stretches is increased, which in the short term brings some relief but subsequently attracts even more traffic, with the result that distributors at the entrances to towns come under even greater pressure than before. One of the first organisations to carve a new path here was the one responsible for the region around Frankfurt. Its general traffic plan also incorporated 'soft data' (in so far as this affected traffic behaviour). Interconnected scenarios were constructed that included such criteria as agricultural protests and the like. A total of 300 hundred hearings were held with the citizens of the region, which by applying the Sensitivity Model led to a universally accepted land development plan for the area (see fig. 22).

In such interconnected depictions, not only traffic movements but also – and for the first time – political decisions, public acceptance, and perceptions of the environmental situation (qualitative data, in other words, some of it bringing in quite unaccustomed factors) also come into play. But it was only seeing how they interacted that showed where tipping effects and time delays arose, where improvements were purely

illusory, and where feedback loops had the potential to turn what had been intended into its opposite. The complex interconnection of factors and data cannot be directly processed by the brain, so here new computer-assisted thinking aids (such as we present in the third and fourth parts of this book) make very useful additions to our planning tool chest.

Projections and the time horizon

The second exception to the acausality rule (that complex systems may behave like machines within a short timespan) is responsible for other abortive developments. You see, most projections of complex systems work very well within a short period of time. However, it is wrong to assume on this basis that for a longer-term prognosis all that is required is more data of a more precise kind.

That this is behind a fundamental error is something we should have learnt in connection with the weather a long while ago. The wealth of data available today (when there are something like a thousand times more weather stations taking measurements than there were in the 1960s) have indeed been able to make forecasts for the next few hours with very much greater security, which has above all benefited modern air travel. However, the striking thing is that even with such an extravagance of satellite images, thousands upon thousands of weather stations, and precise computer-assisted analysis of the data from these sources, nothing has changed: weather forecasts beyond a 24-hour period are still pretty much random. In other words, the wealth of data has not extended the time horizon of predictions by one iota. The fact is, long-term planning is more than just a longer or more precise version of short-term planning.

Each complex system has a specific time horizon, within which reasonably accurate predictions about how the system will develop can be made. Any forecast beyond that, however, only has meaning on a qualified basis. This deterministic time horizon differs hugely from system to system. In connection with weather forecasting it is a matter of hours. In the economy, depending on the sector, actual developments can be predicted only for days or weeks, never for years. In the system that is football, the time horizon is measured in seconds. Here no sports reporter would dream of predicting, on the basis of precise data regarding the positions of the players, their running speed, and their stride length, taken in conjunction with wind speed and the state of the turf, that four and a half minutes from now the ball will enter the top lefthand corner of the goal.

In politics and business management, however, there is still widespread belief in the validity of such predictions, provided only that a sufficiency of data is available, and year after year millions are spent on growth forecasts, market developments, global energy prognoses, and the like. We want to know what events will occur, but we look outside instead of concentrating on the system itself and how it is going to behave. A completely different way of looking at things is required; we need to stand things on their head, and in the next chapter we shall be examining this in more detail. Because until we abandon our misplaced faith in projections we shall go on pursuing the wrong objectives and continue to neglect, in our planning, the close two-way links connecting our existence to the ecosystems around us.

Particularly if we wish to gauge the long-term development of a system, it is not so much its present state that we need to take as our starting-point, far more the system's overall pattern, which depending on its internal structure will also enable us to say useful things when the individual elements of the system form very different constellations.

It is actually my conviction that with more systemic thinking we could avoid much of what is currently causing us concern: declining export opportunities through lack of innovation, increasing environmental pollution as resources dwindle, or the often wholly wrong investment decisions made on the basis of mindless trend predictions. Perhaps I may be permitted to recall at this point a couple of typical instances of projection-induced collapse. There was the case of German software firm Brokat, a star of the New Market, which under the spell of the slogan 'Only global players will survive' pursued a policy of aggressive growth until its share price suddenly plummeted from 200 marks to nothing. Even more spectacularly, another software giant, Think Tools, with no usable product but glowing forecasts, puffed its market value up to 1.2 billion Swiss francs with nothing but hot air before (having meanwhile taken in such experienced operators as Klaus Schwab of the Davos Forum and Thomas Schmidheiny of Holder Bank, while even the very serious Vontobel Bank had fallen for the newcomer's projections) crashing to nil in the space of a few months, taking with it the hopes of thousands of deluded investors. The uniquely excessive flight of the media group E.M. TV, followed by a dramatic collapse, was in the same category. Swissair, too, succumbing to a kind of folie de grandeur (again in the mistaken belief that you have to be a global player to survive), by constantly extending its network of partnerships and takeovers, pre-programmed its own demise while dragging other airlines down with it – all under the direction of the management gurus of McKinsey. After the turn of the millennium it was mainly the collapse of the so-called 'New Market', following its exponential growth (particularly the shocking invasion of the mobile-phone market), that revealed clearly that the 'shareholder values' by which people were steering reflected neither a company's performance nor its prospects for the future. Even the billions of marks being poured into the probably pointless and, in terms of its application, still quite un-thought-out UMTS business may one day (should it fail to become a business) turn out to be so many billions lost.

Such investments, betting as they do on growth, have benefited not least from the perverse dominance of virtual stock-market values coupled with modern computer link-ups, which make it possible to send gigantic sums of money hurtling round the globe in seconds. We have seen (in Asia, for example) how entire economies can be set tottering in this fashion. Even super-speculator Soros (himself not entirely innocent in this regard) recently complained that there is no effective control here. Globalisation of this kind, he says, is a threat to the capitalist system as such, and he has called for new rules o govern the world economy.

Little wonder, then, that the 8,000 bankruptcies a year affecting Germany in the 1980s rose to 40,000 in the year 2000. All these cases show that viable strategies for a sustainable economy can be drawn neither from projections nor from simple economic scenarios; they can only be derived from an interconnected systemic model that takes account of all interests concerned and every sphere of life involved. And it goes without saying that this also includes qualitative factors – factors, for example, having to do with quality of life, consensus, and a blend of functions, none of which is susceptible of precise measurement.

When systems cybernetics becomes part of the equation, the type of prediction also changes. These are 'what-if' forecasts, based on a kind of 'systemic-sustainability check' – very much like 'total quality management' applied to the system concerned. The prognosis, in other words, relates not so much to what will happen when, more to the way in which the system will behave; it will say how the system will react to specific interventions.

Part 2
What our situation requires

Introduction

Because of its ever-increasing complexity and the growing flood of information, our civilisation will succeed in evolutionary terms only if it acquires a far greater knowledge of systemic connections and the laws of cybernetics than the monocausal perspective of our traditional education is able to convey. Since our usual methods of planning are not up to providing decision-making aids for a sustainable way of running the economy, we need training in pattern-recognition that will enable us to understand complex systems with the help of only a few regulatory parameters – not very clearly, it is true, but nevertheless correctly. The following chapters provide an introduction to the new systemic way of seeing things. Interpreting a checklist of eight basic rules will show how organisational bionics can be implemented practically for strategic-management purposes, and with the help of a diagnosis-therapy pattern further tools for dealing with complexity will be identified. It will be explained how fuzzy logic theory makes it possible to overcome the deficits of the 'technocratic constructivist' way of thinking and to recognise complex systems and the way in which they behave by establishing structures of influence with a small number of key data, thus smoothing the way from a 'classification universe' to a 'relational universe'. The resultant working steps towards understanding, interpreting, and evaluating an interconnected system are initially presented in general terms and the need for a recursive way of working explained. There thus emerges almost automatically from the biocybernetic approach the basic theme of a new way, which is then set forth in detail in the third part of the book, using practical experience gathered with the computer-assisted tools of the Sensitivity Model – our 'System Tools'.

6 • A new view of reality

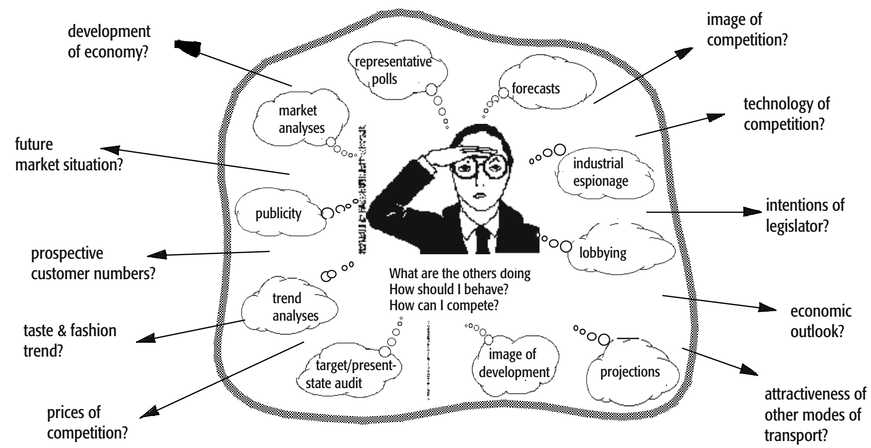
If our aim is to understand a complex system (be it a company, a city, a region, or a transport or energy system) in terms of its behaviour and viability in such a way that meaningful strategies can be developed as a result, there are two respects in which this calls for a reorientation of our decision-making processes: firstly we should stop trying to predict the future by projecting trends and by polling experts in ways aimed at processes that lie outside any system, and secondly we should back away from tackling certain problems in isolation and thereby saving ourselves the trouble of examining the relevant system. Instead we should try to create situations within that system in which (ideally) such problems never even arise. To gain the requisite access to the essence of a system we must first 'invert' our way of seeing things. The art of interconnected thinking starts, as it were, with a viewpoint, a way of looking at the world you live in.

Normally, you are inside the particular system, looking outwards. You take your bearings from what is happening outside. What are the neighbours doing, what is the competition doing, where does the dollar stand, what are the Japanese up to, how will the market unfold, and so on. To answer such questions you consult the experts, conduct market analyses, make projections. But these will give you no information about your own system (and usually, be it said in passing, no reliable information about anything else, either – as witness the annual forecasts of growth and business put out by the 'major' economic-research institutes).

However, with a systemic way of looking you step outside the system, look in from that viewpoint, and mainly examine your own system and how it behaves. As a result, you ask quite different questions: where are the critical points, where are the buffer zones, which levers can be used to steer the system, which not, how flexible is it, how does it regulate itself, how good is it at innovating, where are the opportunities for symbiosis, where do dangers of collapse threaten, and so forth. Here too

Usual, non-systemic approach

Direction of view: I am on the inside, looking out



That way I learn nothing about my system (nor, incidentally, about anything else!). So I need to reverse my direction of view.

Linear corporate model

Intellectual approach
constructivistic
deterministic
production-oriented
technocratic

Goal
boosting sales
short-term maximisation of profits
production growth
larger market share
In trying to foresee the future, one targets specific states.

Orientation
Mainly towards the competition. This gives rise to a company whose gaze is fixed outwards; the only 'inwards' questions it asks are: 'How big is my market share?' 'Where are there still opportunities for rationalisation?'

The cybernetics of the system remains a closed area.

there are analysis tools: effect structures, matrices of influence, policy tests, simulation models. The very type of prediction by which you take your bearings comes out quite different. Ultimately, prognoses are no longer addressed speculatively towards the outside (looking for the occurrence of hoped-for or feared events – in other words, for what is unpredictable anyway in an open, complex system). They are directed inwards, focusing on the behavioural pattern of the particular system under observation: how will it react to relevant events, how robust is it, how flexible, how can its behaviour be improved? Such questions give rise to a systemic, sustainable strategy that may look un-thought-out but was sourced from within the actual system. It reflects neither dogma nor the policy of a political party but only the system itself.

To enable the difference between the two ways of seeing to be demonstrated visually and tangibly as well, my Study Group for Biology and Environment has designed an 'inverting cube' [Umstülpwürfel], based on a model by M.C. Escher, which can be assembled in next to no time.

By 'inverting' your line of vision and the knowledge acquired thereby you almost automatically get a wealth of new decision-making aids and strategic pointers. The reason for this is that the strategy itself is no longer directed at strategic sub-goals such as an annual sales increase, the quickest possible return on investment, or extracting the greatest possible profit from a present (or anticipated) event but at making the system behave in a way that will be as stable under disturbance and as fault-tolerant as possible – which will inevitably also mean economic

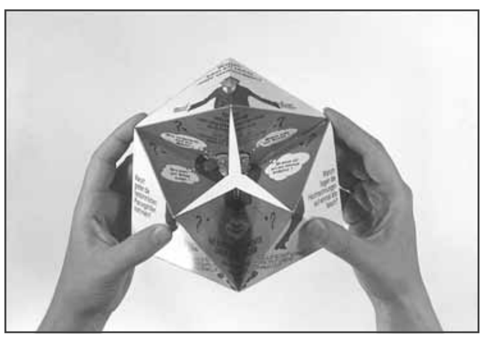
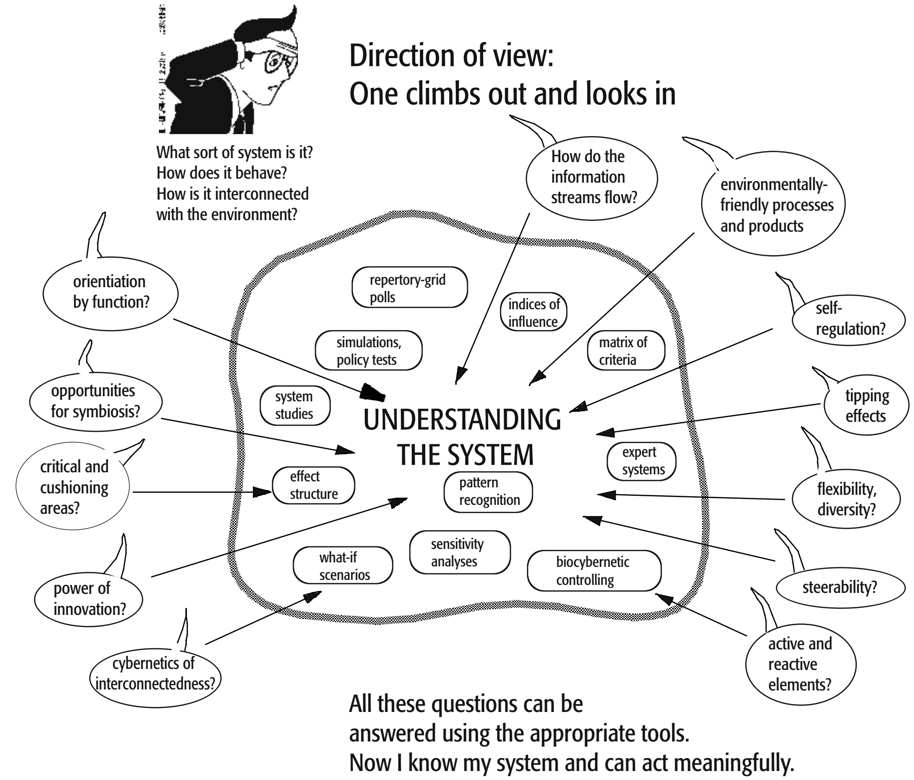


fig. 23a & 23b: **Inside-out cube, based on a model by M.C. Escher**

New, systemic approach



Interconnected corporate model

Intellectual approach:
evolutionary
holistic
function-oriented
cybernetic

Goal:
Strengthening the company's viability and steerability. One aims to 'bow to the future', striving to achieve not states of existence but skills.

Orientation:
On the example of living systems. One's own company is seen as an organism within a larger system. So one keeps an eye on the following: What overall ecological effects does the company have?

What effect in the field of social psychology do its products have? How do they affect environment and habitat?

We are the only companies,
that are pleased to see less consumption. Because we are not a group that with the purchase of more and more power simply pays its shareholders a handsome dividend. We are service partners of citizens, because we, the municipal service companies, belong to the citizens of the municipality concerned. Economic viability is among our corporate objectives, but with us a high priority that looking at the income figure is taking responsibility for the environment. Which is why we emphasise energy saving, rely on the latest technology (e.g. combined heat and power generation), and promote renewable energies including the harnessing of solar, hydraulic, and wind resources. The future lies not in ever-increasing size and might; the responsible future will be decided locally. The responsible future will be decentralised. **Association of Municipal Companies** *[Verband Kommunale Unternehmen or VKU]*

stability as a result of enhanced viability through greater 'cybernetic maturity'. With interconnected thinking, we no longer rely from the outset on isolated solutions but try by adopting a holistic approach to kill the maximum number of birds with one stone, so to speak.

Unfortunately, linear thinking and the resultant progress criteria often still dictate the goals of industry's development departments. In terms of long-term development, however, progress today cannot possibly remain identical with those properties of 'more', 'faster', 'bigger', and 'farther' that (with one eye on the competition or other countries and none on how such properties affect the system at home) we tend to equate with progress. Looking inwards instead, it has long been apparent that other properties ('lovelier', say, or 'smaller', 'more fun', 'less polluting', 'healthier', 'more flexible', 'more transparent', 'self-regulating') have become indicators of economic progress in the sense of the kind of development that is sustainable. So any product innovation must be preceded by innovation in the realm of criteria (some examples are 'smaller and handier', 'quieter', 'more leisured', 'stress-relieving', 'decentralised', and again, 'more transparent', 'self-regulating') if the new products are to represent genuine progress over the old ones. It should be clear by now that the urgent need to save energy (the 'less' criterion) in the wake of the 1973 oil crisis led to much more promising innovations so far as the future is concerned than current efforts to generate larger and larger amounts of energy. Here, of course, the legislature too must in future adopt the same flexible, forward-looking attitude as the entrepreneur and distinguish itself by making some bold decisions. This is already acknowledged in certain quarters, which gives grounds for hope. For example, the German Association of Local-Government Businesses [Verband kommunaler Unternehmen or VKU] presented itself to the public through a full-page advertisement headed by the slogan 'We are the only companies that are pleased to see less consumption'.

They are saying quite clearly, 'The cheapest power is the power that no one consumes.' An increasing number of developments (not just in local government: also in the corporate sphere) follow a holistic philosophy and take the cybernetic intellectual approach. Confidence is growing that what often seem the insurmountable economic, ecological, and social problems of our industrial societies and those facing the Third World (which we are unfortunately drawing deeper and deeper into our own ecological dilemma) are entirely solvable if we use interconnected strategies. This advance guard, too, sees clearly now that if we are to do this we have to leave our monocausal thinking behind. As a systems study of DaimlerChrysler AG written by Michael Steinbrecher under the title 'Research, society, and technology' [*Forschung, Gesellschaft, and Technik*] says in this connection, 'In the face of galloping complexity and a constantly changing social and economic framework, companies are having to look for fresh intellectual and executive approaches that will enable them to go on operating successfully in the marketplace of the future. Because clearly it will not be possible to meet future challenges with the traditional, technocratically-oriented type of management where the main objective is to maximise profits in the short term.'

Regarding the demands that this places on entrepreneurial behaviour, the study goes on to say, 'Rather than go chasing after short-lived developments and fashionable trends, a systemically managed company will understand and, when reaching its decisions, take account of the interconnections and dependencies of the system as a whole in order to develop a long-term view and a strategy for action that is aware of what its consequences might be.'

What actually is ecological thinking

It is a fact that not only socialist structures are in meltdown; so are the intellectual and organisational structures that have prevailed up to now in capitalist industrial enterprises. They too have entered a phase of technological and social change, and this is placing them under increasing pressure. The outward metamorphosis that is taking place here necessarily calls for an inward transformation of our thinking and planning if we are to have any hope of coming to terms with the changed situation resulting from the drastic increase in population densities and the associated problems of supply in the fields of technology and communications; from the more and more complex interactions of our activities and interventions and the ever-increasing throughput of raw materials and energy that these entail.

This does nothing to alter the trend towards economic globalisation, in connection with which Nobel-winning economist Maurice Allais says that, while it benefits certain privileged groups, the interests of those groups cannot be equated with the interests of humanity as a whole. 'Overhasty, disorganised globalisation,' he warns, 'can only give rise everywhere to unemployment, injustice, and instability.' An article in the German weekly *Der Spiegel* (from a series marking the 'Century of capitalism') reaches a very similar conclusion: 'The victorious advance of capitalism seems to be tearing down all boundaries. The magic of the market promises the world more prosperity and greater security. At the same time, social tensions are on the increase and the gulf between winners and losers grows deeper.'

Welcome as the mounting criticism of this development is, one is struck by the fact that none of these analyses even so much as mentions our simultaneously threatened (because increasingly de-natured) ecological life-foundations, which are ultimately also the foundations of all economic activity. The fact is, virtually no ecological thinking takes place in the 'higher' reaches of the business and financial worlds and in associations acting at that level – unlike in many companies. And this is despite constantly repeated warnings from individual authors (including myself) as well as from such serious organisations as the World-Watch Institute, Greenpeace, and the World Wildlife Fund. Even the International Red Cross in Geneva warned in the summer of 1999, in an official appeal to governments, of an 'Era of Super-Disasters'. However, the appeal culminated merely in a call for 'developed countries to provide more capital for the prevention of avoidable disasters' – as if the requisite metamorphosis of our entire economic approach were simply a matter of money! Thinking directed towards what is really needed ecologically is clearly absent here too.

What exactly is truly ecologically-oriented thinking? Is it just an insight into the need for more environmental protection? Does it simply herald a new 'back to nature' campaign? Is it about saying 'no' to nuclear power, refusing more and more 'foreign substances' in our food, turning to 'organic' products. In my view, the switch to such thinking has to start at a far deeper level. The fact is, ecology as theory of 'housekeeping' (in its broadest sense) is less to do with numbers, measurement data, and definitions of things and far more to do with their mutual relations, the way in which the individual components of an ecosystem are interconnected and mutually regulatory, sometimes excluding and sometimes reinforcing one another. And since reality is always inter-disciplinary, any consideration of an ecosystem as a complex system must also, from the outset, be prepared to cross all subject-boundaries. Properly understood, ecology is perhaps the only branch of science that looks not at the thing itself, within its particular category, but at the network of relations among things, spanning all categories. This means that what is crucially important is not humankind alone, nor is it nature alone, but the relationship that exists between them.

Looked at from this standpoint, setting the required course includes a demand that short-term thinking in purely linear cause-and-effect relations be superseded and that, instead of concentrating on detailed study of individual aspects, we train our minds to take in the interplay of connections. Only in this way shall we be able to allow for side effects and repercussions in our plans and actions and bring about sustainable (which is to say, evolutionarily meaningful) developments rather than ephemeral and purely illusory short-term booms. (Incidentally, the German term 'nachhaltig' is usually employed in this context but is woolly in comparison with the English 'sustainable', used in the sense of 'self-sustaining'; the phrase 'sustainable development' goes to the heart of this endeavour.) So before in later chapters we turn to the procedural method derived from the Sensitivity Model, which in the context of established intellectual methods may appear highly unusual, we need to familiarise ourselves with a new way of seeing things. This does indeed differ not only from the picture of a fragmented reality that our schooling leaves us with but also from current economic theory, of which Peter Sloterdijk writes in the Swiss business journal *Cash*: 'The organised idiocy we call the economy has us in the grip of its growth mania. The manner in which we produce often does more harm than the product does good.'

To get away (as we so urgently need to do) from this 'growth mania', we are going to need directional help of an entirely new kind. The place where we can find such help (namely, less in 'considered' theories than in the forms of organisation that occur in living processes and in the biosphere surrounding us) will form the object of the following chapters. As a 'company', the biosphere has contrived over a period of four billion years, in defiance of all obstacles, to establish itself on this planet and even to develop further. Today we know that that was and is possible only because all life on earth, down to the tiniest micro-dimensional beings, meshes together and is interconnected. No living creature can exist for itself alone. Only the close interconnectedness of all life makes survival possible. This is true of humans, too: the whole fibre of their being is embedded in this interplay. Every mouthful of food, every gulp of oxygen-rich air, every attack of bacterial or viral infection reminds us of that fact. Only gradually are we beginning to uncover the secret of those networks, most of which are still unknown to us (the majority, in fact, are invisible). We are scarcely aware, for example, of how constantly we depend on microbes. Yet without them we could digest nothing, we should lack essential vitamins, and our skin and mucous membranes would have no protection. It is a similar story with many plants and seeds, insects and worms, birds and beasts, the existence and interconnectedness of which, both with one another and with the soil as well as with water, air, and climate, are as necessary to our lives as our daily bread. Our joy at experiencing untouched nature is only one indication of these things. Indeed, it may be that we are programmed to find nature beautiful, since otherwise we should not know how much we need it. It is the very ground of our being – and we are in the process, because of a few short-sighted, selfish wishes and demands, of destroying it to our own disadvantage. It is high time we see nature conservation from a different angle. It's not about nature's needs; it's about ours!

7 • The biocybernetic approach

The new way of looking at things requires a model that will render this kind of recognition, control, and self-regulation of mutually interacting processes transparent. As in the living world of nature, neither deterministic pre-programming nor central control should be necessary. The steersman is part of the system; steering is limited to the provision of impulses towards self-regulation and the 'touching' of interactions as one might 'touch' the controls of a vehicle. Long-term stabilisation of the dynamics of the system should be supported by flexibility and the harnessing of existing forces and symbioses, with the steersman operating not against but with the system. Problems are solved indirectly, so far as possible, using the situation that the system currently presents; supplementary measures will often be more effective than direct action.

In this perspective, viewed from the biocybernetic standpoint, whether for corporate-planning purposes or for a future urban or regional policy, one aim emerges: not so much to strive for a specific state of affairs, a situation that can be described precisely (such an approach would still be deterministic), more to promote viability as such, together with all its subordinate capabilities, by creating possibilities of respecting the basic rules of cybernetics, maintaining self-regulation, and thus improving survival chances.

What I want to make clear here is that, in our complex world, we ought not to tackle any problem, never mind the context, without first making a thorough assessment of the consequences. However, the only way we can do this is by taking that complexity (in other words, the manner in which different spheres interconnect) into account in our perception of reality. As was stressed in the previous chapter, this means above all examining the system in which the problem occurs, not just the problem itself.

Obviously, then, we are faced with a fundamental challenge in terms of method – in fact, in our basic understanding of how an economy should be run. It is becoming increasingly clear that, with our population explosion, rapidly approaching resource scarcity, and the rampant pollution of the environment with which we live in symbiosis, we are heading faster and faster towards a global economic and survival crisis. But what outside authority is there by which we might, with a clear conscience, be guided? I try in my publications to show with the aid of many examples that, in our search for models, the only solution we shall find that guarantees a reasonable survival period is the biological solution. The fact is, precisely what happens in the biological sphere has indeed survived an immensely long period of trial and error on the rigorous test bed of evolution. And long before we developed our tools and technologies, nature had already produced its own.

In my time as a microbiologist, experimenting with living cells, both cancerous and normal, with the way in which information is transmitted inside the organism, and with genetic and cybernetic control mechanisms in plants and animals, I soon recognised that I was dealing, over and over again, with forms of organisation to be found not only inside the cell but quite as much outside individual organisms – that is to say, in the interplay between them and their environment. It really is true that, in connection with goes on between different creatures in a biotope, an ecosystem, or an economy, very similar communication functions, control mechanisms, and processes of exchange and regulation take place as do between the individual cells or organs of an organism.

In an essay by Fredmund Malik and Gilbert Probst in the Swiss business journal Die Unternehmung ['The Company'] we read the remarkable sentence: 'Ecosystems research, which examines the emergence, configuration, and dynamics of structures of activity, may possibly be of greater importance to business management in future than political economy.' More and more computer scientists, physicists, biologists, and economists are coming round to the view that the special way in which complex natural systems behave offers solutions possessing general validity. Going beyond empirical observation, that view finds its basis in laws capable of theoretical justification, laws that clearly emerge from the very properties of matter and extend from the structure of the atom to the manner in which cognitive processes organise themselves.

My own 20-year career in experimental research resulted in a decision: rather than go on enriching biological science with fresh findings, I would tease out of its existing findings what might be of use not for biology itself but beyond that for our lives, for our understanding of the world, and for help in tackling our problems. In the process I could not help discovering how, as a result of the hothouse atmosphere that exists within particular disciplines and the way they erect bulkheads against other disciplines, much knowledge that might well have borne fruit in other areas remained barred to them. But I also discovered something else: that applying the techniques and reproducing the forms of organisation of that magnificent enterprise known as the biosphere called in turn for precisely the kind of interconnected thinking that is not taught in our schools and universities.

Around the same time a number of other scientists reached a similar conclusion; they included biologist Joël de Rosnay of the Institut Pasteur in Paris, British ecologist Edward Goldsmith, synergeticist Hermann Haken in Germany, cyberneticians Heinz von Förster and Stafford Beer in the USA, and Austrian biologist Rupert Riedl, but there were also economists among them, men like Friedrich August von Hayek, Hans Ulrich, Hans-Christoph Binswanger, Fredmund Malik, and Peter Gomez of the St. Gallen School of Business, and Gilbert Probst in Geneva. Not to mention an expanding circle of people from all professional groups who shared the same intuition: that we must think in terms of open complex systems and grasp reality as a system not made up of separate compartments but needing to be seen as a network of connections transcending subject boundaries.

The reason why so many things no longer function in our industrial society (or function only as additional burdens) is precisely because the cybernetic laws of our world are largely ignored. The only system that, so to speak, still loyally and sincerely goes about its work is the biosphere – trees and leaves, birds, worms, grasses, and the many insects and micro-organisms harmoniously tuned to one another. And it is precisely these imperturbable assistants that find themselves under constant attack from us as we try to undermine the foundations of their existence, poisoning and destroying them. Why? Well, part of the reason is that we know so little about them. The fact is, we have little idea of how the system works and what it actually does, having never felt the need to take a closer look at its organisation.

With its huge annual turnover of many hundreds of billions of metric tonnes of material, the biosphere nevertheless posts nil growth in terms of biomass, and with that it has got by for aeons. And with an enviable yield, too, a vast body of creative development and a wealth of living forms. How does this happen? The answer is: in the enterprise 'nature', management sticks to a handful of cybernetic ground rules – principles as old as the hills, but at the same time supremely relevant.

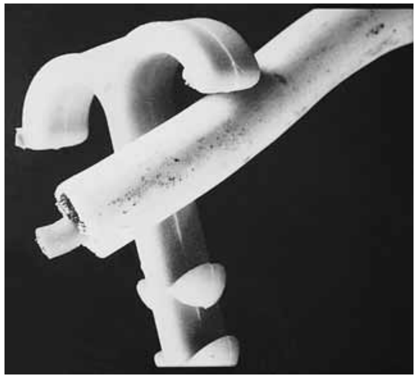
For instance, a closer look at biosystems reveals that in one way or another all our technological appliances and procedures are, so to speak, projections or expressions of biological technologies heralded in our own make-up. Today we are able to trace this in the minutest detail in every living creature, right down to cell level. Molecular biology as the start of a new approach to getting in touch with ourselves!

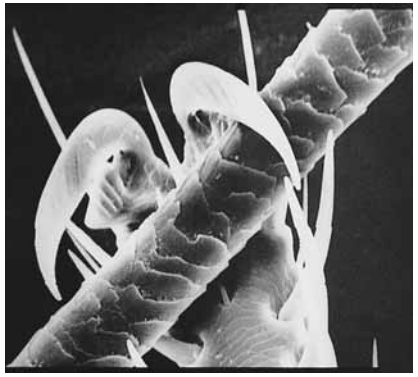
Long before we developed our tools and technologies, nature had already developed them – and not merely on a comparable scale, either (the heart as pump, the eyes as video camera, the kidneys as dialysis apparatus); also in much smaller dimensions, as comparisons with the insect world show.

In addition to those illustrated on the following pages, there are countless instances of astounding similarity between natural and artificial technologies – but only as regards form and function, not (you will notice) so far as organisation is concerned, i.e. the manner in which nature handles their structures and techniques. Here the differences are still huge, because although in terms of structure and function our technology is more or less keeping up, we have never even come close to matching the efficiency of the production processes, product quality, and systemic planning that nature, as it were, holds up to us. Bear in mind that in every single cell of the human body something like 10,000 different processes take place via as many chemical links and 'machines', governed solely by impulses that genetic information provides. They do so, moreover, with a fine-tuned logistics, using a balanced 'range of products' with the same kinds of structure and function as arise in human technology but in quite different ways from those employed in our own factories, so far as the production process is concerned.

Remember, too, that nature's tools and technologies (be they elephants' tusks, lobsters' claws, vast coral structures on the seabed, the sonar

Using electronic half-tone photographs, Saarbrücken bionics expert Werner NACHTIGALL has revealed hundreds of examples of an astonishing similarity between natural and artificial technologies, publishing them in a beautiful book entitled 'Konstruktionen' in Biologie und Technik. Here are just four examples from the insect world.





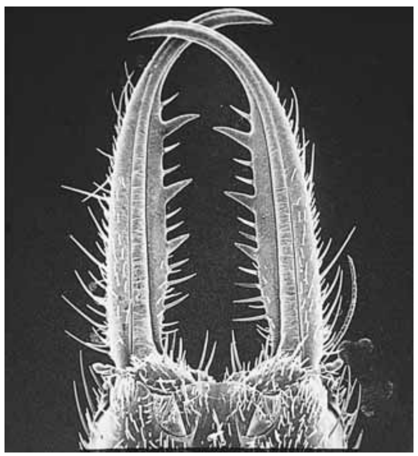
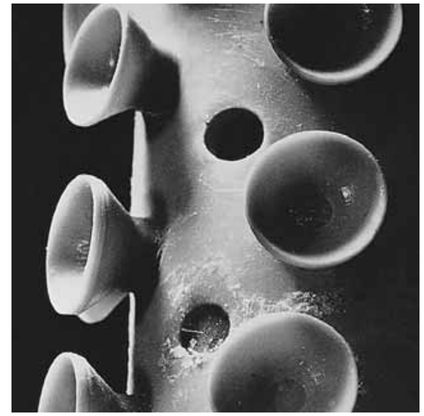
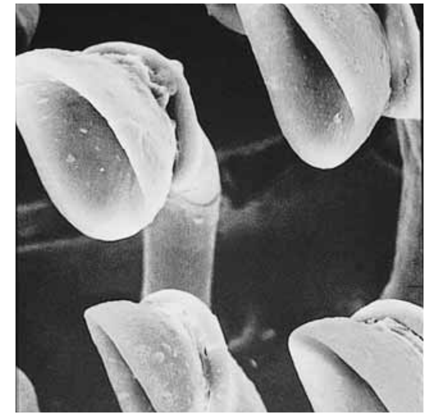
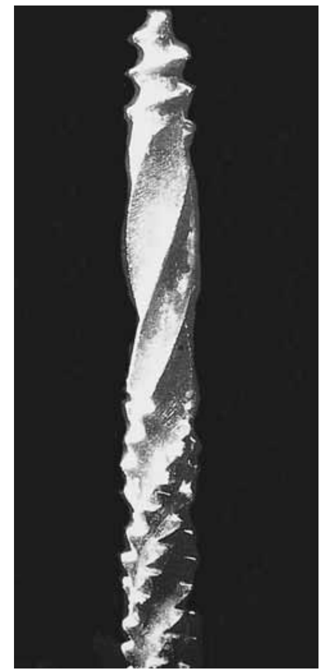


fig. 24 *(top left)* An ordinary clip for securing electric cables
fig. 25 **(top right)** Gripping hook on the foreleg of the dog flea
fig. 26 *(bottom left)* 'Jaws' of a pair of combination pliers
fig. 27 *(bottom right)* Upper jaw of the ant lion or dragonfly larva

antennae of bats, the shells of tortoises, ankle joints, or the countless tubes, valves, levers, and pumps in our own bodies) are all manufactured at temperatures not exceeding 37 °C! Added to which, they are all fully recyclable and involve only minimal consumption of raw materi-







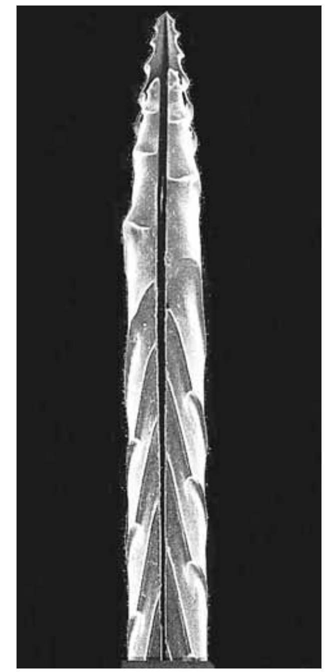


fig. 28 *(top left)* Sucker cups on a soap holder
fig. 29 *(top right)* Sucker cups on forefoot of common water beetle
fig. 30 *(bottom left)* Tip of a bore file
fig. 31 *(bottom right)* Ovipositor of a wood-wasp

als and energy. Whereas we, merely in order to obtain the steel for a pair of pliers, have to achieve a smelting temperature in excess of 1,000°C, which also produces waste heat and exhaust gases, as do the subsequent processes of moulding, tempering, and welding.
Even the most complicated chemical ring compounds or polymers, to produce which our technologies repeatedly have to use high temperatures and processes of distillation and solution, are formed by biomachines such as mitochondria or ribosomes in a most elegant fashion with the aid of special catalysts operating at body temperature. Equally neat is the way chloroplasts, the solar modules of green plant cells, harness the energy of the sun. The internal arrangement of what are termed 'photosynthetic antennae' forms a kind of light collector that multiplies the number of photons hitting a photoactive centre. Energy generation for water replacement then proceeds with what in comparison with the still very crude photovoltaics of our solar-cell technology is well over a hundred times greater efficiency.
Another interesting difference lies in the field of distribution, as it were. In the biological cell there are virtually no overcapacities or shortages or problems of switching from one form of production to another. Once the 'market' (in this case, the cell plasma) can no longer absorb a product, any surplus is no sooner created than it is broken down again to its constituent materials. And this is done with the same machinery as served to produce it.
In fig. 32, all the reaction paths have two arrowheads, signifying that one and the same enzyme catalyses the metabolism process in both directions. The constituent materials restored in this way can then be used for something else. Even in transport, circumstances are the converse of what we usually achieve. In the process of metabolism, relatively enormous loads are transported with a tiny amount of equipment (by sliding, for instance, or by vibration, or by suction), whereas we, on our modern roads, transport a single person with a device that weighs a tonne or more and an infrastructure that does violence to our habitat.
In the course of a myopic boom period, we have developed processes and technologies that, in contrast to the mature biotechnologies of nature, work only with a vast expenditure of energy, equally great energy losses, and a primitive form of organisation; they also, for what they

achieve, require far too much input in terms of capital, equipment, energy, safety, and raw materials while at the same time generating far too much output in terms of effluent, waste heat, stress, damage to the environment, and social pollution.
Why was our own technology, which is clearly borrowed from that of nature, able to come into such collision with its prototype in the first place? There are several reasons. One is probably that, in the arrogance of the burgeoning industrial age, we were simply not interested in the subtlety of nature's exemplary role. For a long time, in fact, people looked down (they still do today, to some extent) on taking nature as the pattern for artificial systems to be created by ourselves. They took the view that nature was primitive and the human mind a cut above it. It followed that anything produced by that mind was far superior to nature. Not until the mounting disasters of recent times, whether in the fields of technology, economics, or medicine, were we led to wonder how the world of nature had succeeded not merely in surviving for so many millennia but in constantly developing ever higher forms. And doing so while the quantity of biomass in existence remained virtually unchanged at a figure of around 2,000 billion tons.

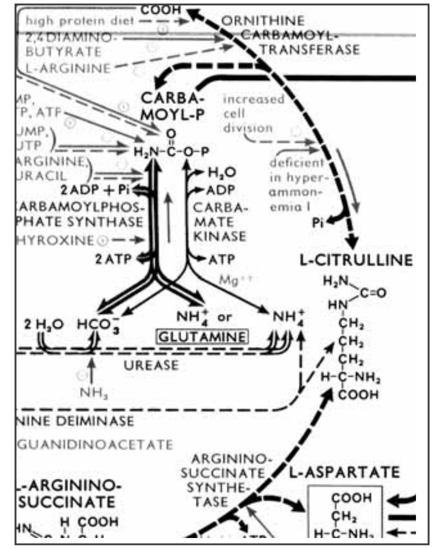


fig. 32: **Metabolism map** (excerpt)

Suddenly we realised that, despite nil growth, several hundred billion tons of oxygen and carbon compounds get converted each year and further billions of tons of heavy and light metals such as iron and vanadium and cobalt, magnesium, sodium, potassium, and calcium processed, in large measure extensively but also, on occasion, intensively, in very great density, within a tiny space but essentially on a decentralised basis, in tiny manufacturing units employing the most sophisticated technologies.
In nature, then, we see a turnover of oxygen and matter of gigantic proportions. Here is a technological supersystem, and one that operates

with an efficiency we can only dream of. We are looking at a form of organisation, a style of management, and a logistics that are not remotely comparable to our own. And we now know how this happens: through clever exploitation of twinned effects, energy cascades and energy chains, symbioses and processes of self-regulation, the interplay of which results, wherever we look, in a useful effect of the highest proportions, be it in the tiny solar-power generators that (as we have just seen) are the chloroplasts found in green leaves or be it in energy-producing mitochondria, the bacterium-sized 'power stations' inside every mammalian cell. This is a system with no resource worries and no unemployment, no distribution problems and no debts, a system that represents a real treasure house of specialised refinements, energy-saving wheezes, and elegant combinations of highly-developed technologies. All these things have helped this unique entity, this 'enterprise', to stay out of the red for four billion years. Studying this system and shrewdly imitating it could, for humanity, become a matter of life or death.

Such imitation, however, is needed less in the sphere of structures and functions (modern bionics has achieved great things here) than in the way in which living systems are organised – that is to say, in the sphere of biocybernetics and evolutionary processes, as studied by Ingo Rechenberg for implementation in industry. Because whether a system is viable or not is due mainly to the way in which its various parts communicate. In other words, it depends on the kind of cybernetic feedback that has underpinned all life on earth from the very beginning.

One need only glance at fig. 33 (the 'metabolic pathways' that exist inside a single human cell with its 10,000 functions, of which the figure shows only a small fraction) to gain an impression of the complexity of this manufacturing operation, from the informatics, energy economy, logistics, and marketing of which any manufacturing company could learn a great deal in terms of 'total quality management'. This touches on the area within which I operate in the main: namely organisational bionics, a much-neglected subsection of informatics that enables us to learn not only from structures and techniques found in the natural world but also from the way nature manages those structures and techniques.

Organisational bionics, therefore, means above all supplementing logic

with analogic. As regards spotting connections, it can be extremely useful to trace analogies to living systems – which is of course another thing that can only happen across subject boundaries. However, it opens up some extremely interesting fields of knowledge, not only as regards developing our own technologies but also as regards the type of our organisational forms and hence of our management. What we can learn from the cell as production unit and the products manufactured therein has (as already emphasised) an enormously long testing and development phase behind it. We need to take advantage of this. There is a vast field of potential innovation lying fallow here (which is why the bionics aspect so urgently belongs in every specialist education programme).

Clearly a bionic and cybernetic consideration of natural processes carries with it above all the enormous risks involved in any technology that has not been thought through. From the bionic viewpoint, the most obvious of these are the microelectronics and recently also the micromechanics of nature: bacterium-sized relays, almost infinite storage capacity through combination and permutation, as in our chromosomes, scarcely any material requirement, minimal energy consumption, very little space needed. Yet here too the differences are enormous. For instance, unlike the microchip in an electronic brain, each of our brain cells contains in its chromosome code the basic building plans of the entire organism. But the insights of bionics also show what unsuspected possibilities exist within the biosphere, considered as the oldest business in the world, possibilities that have never yet been exploited. If we follow the rules of bionics, the dominant human species will continue to participate in the general unfolding of natural life very much to its advantage. Claus-Dieter Vöhringer, head of research at DaimlerChrysler, speaks out clearly in favour of this option in the German science journal Bild der Wissenschaft: 'The aim,' he writes, 'is to create technologies that match human insights, thinking, action, and communication better than hitherto, technologies that are more patterned on nature. Any technologist who thinks in the longer term will inevitably see nature as the ultimate model.'

Potentially, there are incalculable benefits to be gained from a more intensive use of bionics – in other words, from copying nature's tricks.

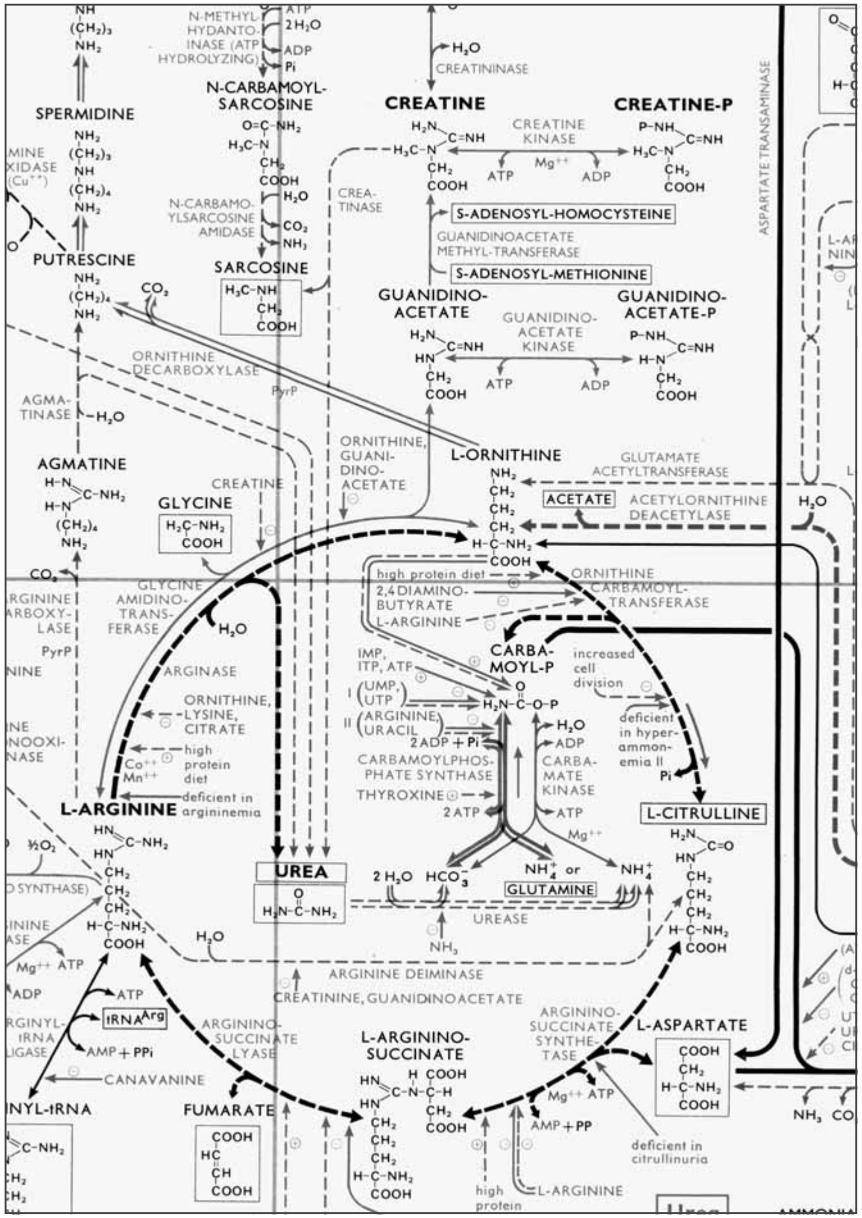


fig. 33: **Metabolism map** (excerpt illustrated reproduces approximately one-eighth of full map). From Biochemical pathways, (ed.) Gerhard Michal, Wiley

Bionics has the capacity to impart a fresh direction to the flow of information between human beings and their environment: from nature to us rather than the other way around. This is very much what is happening in today's gene technology, for instance, where the direction has indeed been reversed: genetic manipulations are being used to impose our meagre knowledge on nature in a process that is coupled with unforeseeable consequences, any attempt to assess which is more than presumptuous, given the present state of science and the technological means currently available to us.

Unfortunately, the arrogance of civilisation has long nourished in us the belief that we can replace the laws of cybernetics with other mechanisms, designed by ourselves, apparently more profitable, yet generating systemic stress. Bionics teaches us to heed nods and winks from the natural world and imitate models capable of producing similarly system-friendly results for ourselves.

If we do not wish gradually to destroy the biosphere as the irreplaceable basis of our existence, we cannot do otherwise than obey certain fundamental systemic laws in the way we do business as well. Certainly, the result of our existing practice of ignoring them altogether is that, rather than creating corporate ecosystems, we are producing increasingly sick systems that are now lying in a coma. We can keep them alive for a while artificially, in 'intensive care', but we have the very much better option of preventing such cases from arising in the first place by adopting planning methods appropriate to systems. And we can do this without either making sacrifices or practising renunciation. We can achieve much by rearrangement, reorientation, reorganisation, and by replacing and reshuffling procedures – in a word, by effecting a technological and economic change, as is indeed slowly starting to happen.

Currently, the change is going through several stages simultaneously. In many areas the old phase of aggressive technology and economic management has already given way to a repair phase, as witness wastewater treatment works, desulphurisation plants, or catalytic converters. Yet this repair phase can itself only constitute a transitional stage towards a biocybernetic technology and a type of economic management that takes the whole system into account, one that embraces all the conditions to which we living creatures and the artificial systems created by ourselves are subject. In addition, we need to check the extent to which our technology and formal principles are in harmony with what we might call the 'ground of their being', which as I have tried to show has its roots in the natural world and not in dead matter, which is alien to any kind of technology. Nature and technology do not constitute different worlds, as is so often thought; nature itself, hence also our own organism, is chock-full of technologies.

Unconscious imitation of the structures and functions of nature occurred previously in the erroneous opinion that this was all that was needed for a fully-operational overall system. We forgot, in the process, to think also about nature's forms of economic organisation and the basic rules it observes in making use of those technologies. Only all three (structure, function, and cybernetic organisational form) will guarantee integration in the system 'biosphere' of a kind that is going to last. Yet this is precisely where our industrialised society might one day come a cropper, the reason being that the rules of organisation become important as soon as we are dealing no longer with separate 'machines' but with interconnected systems.

The biocybernetic intellectual approach makes new standards of value necessary in practically every area of our civilised society. All the way from light engineering and vehicle-building, through architecture and industrialised agriculture, to our transport systems and the technology-heavy weapons systems of our defence concepts. Yet as soon as we accept a system-related intellectual approach, unsuspected developmental possibilities will emerge spontaneously for our densely populated planet.

As a systems-analyst with a natural-sciences bent, who has spent much time studying the cybernetic structures of the living world and the bionics of their brilliant form of organisation, I venture to state that we are not at the end of an era of technological and economic innovation but, assuming a swift and bold assault on the problem, only at its beginning. However, the condition of this is that we learn to say goodbye to the 'progress criteria' that have so long been seen (ever since the Industrial Age began, in fact) as the foundation of economic prosperity.

8 • Recognising complexity

Superficial solutions are tempting. In one's enthusiasm about having seen a solution and found a way of getting rid of a problem, one is reluctant to put that solution at risk; consequently, one guards against any hint as to how complex things actually are, although one would be quite capable of recognising (and of course exploiting) the links with the rest of the system if one wished. The fact is, a simple simulation model would soon make plain that a problem is not necessarily best tackled in the place where it occurs; often there will be far more mileage in allowing interconnections already in the system to take effect – in other words, in adopting a cybernetic approach.

Particularly some of humanity's newer problems to which the population explosion has given rise, such as the inordinately large energy throughput, more intensive agriculture, and the looming scarcity of resources, not to mention the increasing frequency of 'systemic diseases' (cancer, AIDS, allergies, circulation disorders, and so on), which place great burdens on public health – those problems are highly complex, and because of the still unknown ways in which they are linked together they cannot be controlled by non-interconnected thinking. Here, to take some examples, I should like to touch on three areas that look completely different depending on whether we consider them in a 'linear' or 'interconnected' fashion: the nuclear-energy adventure, the outlook for genome research, and attempts to still the world's hunger with genetically modified foods.

The nuclear-technology adventure

In 1978 (8 years before Chernobyl), at the inauguration of my travelling exhibition 'Our world – An interconnected system' [*Unsere Welt – ein vernetztes System*], I issued a 12-page illustrated booklet entitled 'The (rotten) egg of Columbus' [*Das (faule) Ei des Columbus*; allusion to the

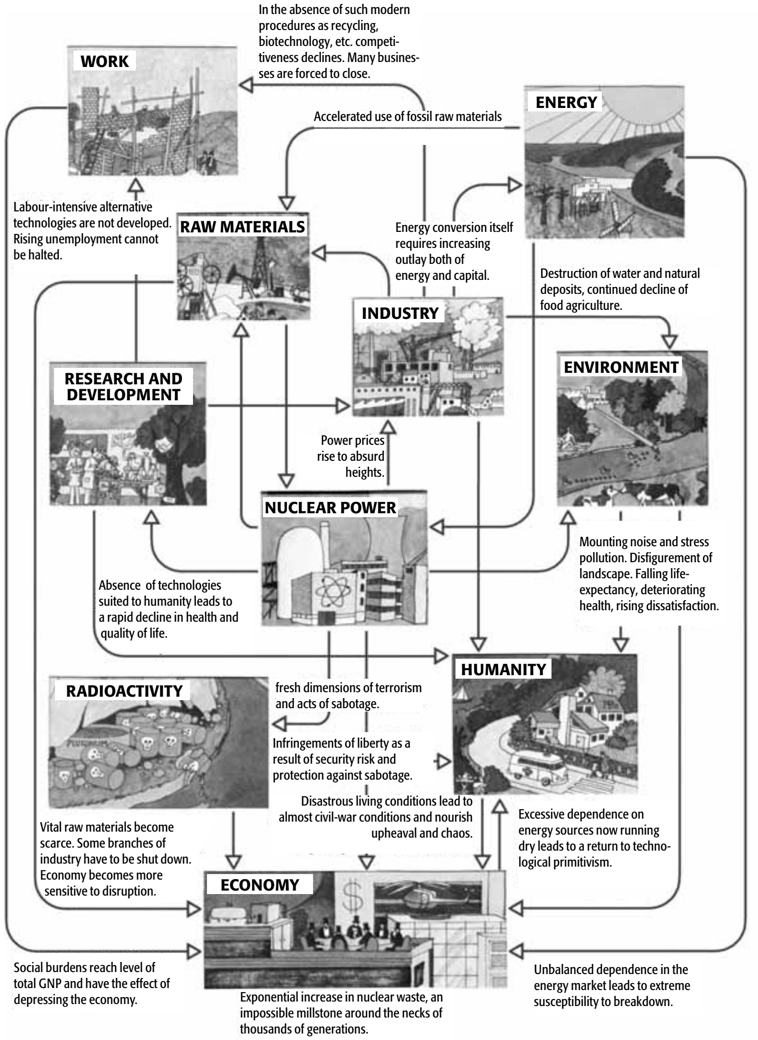


fig. 34: Overall network of the implications of nuclear energy, as built up step by step in the author's 1978 book 'Columbus's (bad) egg' *[Das (faule) Ei des Kolumbus]*, on the basis of interconnections already becoming apparent.

famous story of Columbus and the egg has achieved symbolic status in the German language, where it signifies 'a solution of striking simplicity' (Tr.)]. In the booklet I demonstrated how nuclear energy is interconnected with the other spheres of life in our civilisation (see fig. 34). Because of the complexity of that interconnectedness, I put the likelihood of an MCA [maximum credible accident] at a very much higher level of probability than 'once in 10 million years'. This provoked a storm of protest in the nuclear-energy lobby and the government departments in thrall to it. The highpoint was a defamatory pamphlet (twice as long) published by the German 'Association for reactor security' [*Gesellschaft für Anlagen- und Reaktorsicherheit or GRS*] with the title 'The rotten egg of Dr. Vester' in an edition of 10,000 copies. In the mean time, as well as the 'maximum credible accident' then still considered impossible, most developments have taken the form I described.

That in the light of so 'ideal' an energy solution people should close their ears to such objections as the exponentially increasing problem of nuclear waste as well as (after Chernobyl) the profound effects of sources of incorporated radiation (in no way comparable to the effects of normal cosmic radiation) expressed a kind of fundamentalism that is no longer open to scientific discussion. On the basis of my own research activities in the 'nuclear city' of Oak Ridge [in Tennessee, USA, home of the US Department of Energy's Office] in the 1950s and later as visiting lecturer for many years at the Karlsruhe Centre for Nuclear Research, where I helped to develop the radiation biochemistry courses, these things were naturally familiar to me. Whistleblowing about these adverse 'side effects' soon got me into deep trouble, and at the time I had to face some frenzied public insults. Since the direct and indirect interconnections of nuclear energy are still not generally acknowledged, let me briefly, in ten points, summarise them again here:

1. Failure to recognise the complexity of the nuclear-waste problem

In the first flush of enthusiasm about the peaceful use of nuclear energy in the 1960s, radioactive waste was never talked about. Any waste that did occur would be minimal, people thought, because the annual quantity of fuel needed for a nuclear reactor would fit into a small suitcase. As early as 1968 my book 'Building-blocks of the future' [*Bausteine der Zukunft*], followed 2 years later by the study 'The survival programme' [*Das Überlebensprogramm*], drew attention to this twofold piece of self-delusion. In the first place, radioactive waste products can never be 'eliminated' because no matter what form they are chemically transformed into they never lose the radiation associated with their atoms. Secondly, the amount of such waste, which was indeed laughably small at first in comparison with the fuel used in a coal-fired power station, will nevertheless increase exponentially. This is a problem that humanity will face for all time (in Russia, radioactive contamination is already out of control, and the reprocessing plants at La Hague and Sellafield have both become permanent 'suppliers' of contaminated wastewater to the environment).

2. Repescussion to the legal situation

Permission to operate a nuclear power station has always been (and still is) bound up with evidence that radioactive waste will eventually be got rid of completely. However, for the reasons (springing from laws of nature) just mentioned, this will never be possible. So to circumvent the law it has been necessary to pretend that one day it will in fact be possible. Hence, in the light of current efforts (futile in reality), the issue of provisional permits – simply to keep the business alive. In actual fact, not a single nuclear power station in the world has a legally admissible permit to operate. We get around this problem by continuing to work on the final storage or transformation of nuclear waste. We bridge the situation with interim storage facilities, wrongly positing the technique of reprocessing (with its plutonium problems) as disposal.

3. Irritation of insurance companies

A further point underlining this lack of legality is offered by the insurance situation. The major insurers and reinsurers, while covering losses arising out of an accident for the power station itself, pay no claims whatsoever in respect of consequential losses inflicted by a disaster such as Chernobyl on the area contaminated by radioactivity as a result. Before Chernobyl it was possible to use the improbability of a MCA as an excuse and weigh up a large number of moderate insurance costs (frequency of minor breakdowns) against the one-off but decidedly immoderate costs of a single (yet highly unlikely) MCA. Those days are over. However, since insurance companies will still not accept liability for an MCA, in principle not a single nuclear power station should still be in operation. Yet the fact continues to be repressed. In France it was not until 2001 (15 years after Chernobyl, in other words) that the first case was heard in which radiation victims successfully defended themselves against the then official 'explanation' (backed up by falsified weather reports) that the radioactive cloud ought to have halted at the borders of the *'Grande Nation'*.

4. A way out of the CO_2-dilemma?

After not just the USA but also other countries such as Austria and Sweden decided to issue no new permits for nuclear power stations (much to the dismay of the companies that build them) and Germany too resolved to get out of the technology, as a last straw the use of nuclear energy as an (indispensable) answer to the greenhouse-effect problem was tossed into the debate. Here again the thinking was not interconnected and the complexity of the problem went unrecognised. Just two points on this: Firstly, in the whole process of nuclear-power generation, all the way from uranium tailings to the manufacture of cement for the reactor's safety container (converted into kilowatt-hours), at least as much CO_2 comes into existence as when a modern gas-fired power station is built – not to mention that the krypton 85 released is itself a highly effective greenhouse gas. Secondly, it badly needs to be made clear that the ca. 434 nuclear power stations currently in operation around the world supply only 5 per cent of its energy. Even if nuclear power stations were to cover only half our energy requirement, we should already need to build more than 4,000 (!) new ones. Where are they to be sited? Who is to pay for them? What is to be done with the exponentially growing amount of nuclear waste? To say nothing of the far greater risk involved (including acts of sabotage). Pity: it would have been nice to have ready access to so lucrative a source as 'clean' nuclear energy for future energy supplies involving no 'greenhouse effect'.

5. The MCA that 'will never happen'

A similar narrowing-down of complex circumstances could be seen in the fact that for years it was regarded as extremely unlikely that an MCA would ever happen. As long ago as 1979 the breakdown at Harrisburg might have shown the degree of danger that exists if, as regards calculating the incidence of technical faults, operating a nuclear power station is seen as a closed system. The fact is, like all real systems this one too, despite every redundant safeguard, is still open to outside influences. That means, such a system has to be fault-friendly. In other words, no one should assume that everything will work; the system also needs to be robust in the face of unexpected mistakes and omissions – by the operating crew, for instance, or as a result of computer breakdowns, wrong estimates, repair work (as at Chernobyl), and other external occurrences, not to mention earthquakes, plane crashes, and attack by terrorists. When the rarity of an incident is weighed against the enormity of the loss to be expected, no insurance company is going to accept liability (as is in fact the case).

6. The peculiar nature of incorporated radiation

Another false assessment reached along linear channels of thought concerns the danger of radiation itself. A hardy misconception in many minds is that, so far as the populace is concerned, the fallout from reprocessing plants or after something like the Chernobyl accident is negligible since (allegedly) the becquerel count received is roughly the same as we get from cosmic radiation when climbing a mountain or flying across the Atlantic. Even the German Reactor Safety Committee (clearly concerned to keep the peace at all costs) has spread this dangerous nonsense, which makes me sceptical regarding its objectivity. In reality, there is a fundamental difference here. In an article in a major German newspaper, the *Süddeutsche Zeitung*, that was published a few days after Chernobyl, I wrote (backing my argument with a series of tables), 'Radioactive matter resulting from a reactor accident can (in principle, without exception) be taken up by the organism. When this happens, the radiation source itself sits inside the body and continues to give off radiation, even if this cannot be measured from outside. Moreover, the radiation has a concentrated effect on the surrounding tissue (and on the DNA contained in that tissue), which may no longer have the capacity to repair any damage inflicted. Accumulation through the food chain may, over time, result in a magnitude of several thousand or even a million above that of the environment. (The article, because of what was otherwise a very inadequate information policy, was reprinted hundred of times and eventually dealt with in detail in my paperback 'A mix-up: the result' [*Bilanz einer Verwirrung*, 1986]. How appalling that 'result' has been, even just in Russia (and not merely post-Chernobyl but also because of the mounting contamination resulting from normal operation and the irresponsible dumping of nuclear waste, some of it imported for cash), has since been made quite clear by reports in the press and on television.

7. Narrowing energy supply

An incidental effect of neglecting complexity is one-sided promotion of this source of energy (which for the layman holds a certain fascination; basically it is 'low tech', because as with a steam engine all it involves is heating water to a high temperature – unnecessarily high, actually – to drive a turbine and a power generator). For decades now, the public money available for developing energy supply has been channelled almost exclusively into nuclear energy. Because of this, development of renewable forms of energy (the only alternative with a future but into which, up until 2000, only something like 1 per cent of that money flowed) has effectively been starved of funds. Even in the sunny South of France (and I have personal knowledge of the situation there), complete ignorance prevailed as to the possibilities presented by solar energy. The view that none of it worked, that it was very costly and delicate, would never pay for itself and in winter produced nothing anyway was vigorously maintained by such leading energy organisations as EDF and Framatom and their experts. Not the least of the factors playing a role here was that France (which unlike Germany was able, under the nuclear treaty, to manufacture nuclear weapons) could pronounce everything to do with nuclear energy strictly secret, thus enabling the state and its wholly owned subsidiary EDF to cover up anything unpleasant without the inconvenience of public discussion and involvement and steer whatever course they liked. Remembering too that over decades vast sums of money were poured down the 'fast-breeder' dead end (the 'Superphénix', abandoned only in 1995) and that further sums are still being poured down another (seemingly clean) dead end called fusion energy, one wonders how the scientific consultants responsible can sleep at night.

8. The hot egg of Columbus

The fact that, with the disadvantages of nuclear energy (particularly the hopeless prospect of disposing of waste) gradually dawning on even the nuclear energy lobby, people initially took refuge in the 'fast breeder' (which promised to solve the waste problem) and 'clean' fusion energy (dubbed 'the hot egg of Columbus') is a typical instance of the third of the six errors listed in chapter 2: irreversible foregrounding. Both the 'alternatives' were based on nuclear research (the atom must not be abandoned as the ideal solution), with the result that, rather than genuine alternatives such as renewables being funded, yet further billions were poured into what must eventually turn out to be dead-end projects, each with its own fresh disadvantages.

Indeed, with fusion research things started off just as they had with work on fission reactors. Once again people simply ignored the fact that the end result would be a monstrous mountain of nuclear waste. Yet still today people only consider (not looking beyond the ends of their noses) the fusion reaction itself, where it is true that, in contrast to fission, no radioactive waste is created in the actual process. However, that the energy of the neutrons generated can be rendered usable only when captured by the right target matter (which produces far more radioactive waste than is the case with fission) – oh no, people are careful to avoid thinking that far. Had the people putting up the money been told about this, no doubt the huge sums poured into what has long been seen as the nonsensical development of fusion energy would never have been made available. As early as 1980, particle physicist Jochen Benecke of Munich's Max Planck Institute, on top of his contributions to the specialist literature, made this very point in the cover story of the October issue of the German science journal *Bild der Wissenschaft*. His action ought really to have resulted in funding for research being shut off instantly.

9. Interconnectedness with the economy as a whole

Quite apart from the incidental effects and interactions of nuclear-energy development, the overall system of our civilisation on which it impinges would suffer not only the consequences described but also economic repercussions and feedback effects that would scarcely contribute to an economy oriented towards the future. Because what would have been gained if we really did one day have access to an unlimited source of safe artificial energy? How would the economy run? What would happen to management of resources? Would world hunger be conquered, the greenhouse effect abolished?

For a start, something would have to be done with the electricity (we often forget: the only thing you can do with nuclear energy is make electricity). You can't stick electricity in your pocket or put it in the bank. Consequently, production on an inordinate scale would set in, accompanied by an equally inordinate level of consumption. Material consumption on the basis of resources that are already running out! The limits to growth would be reached far more quickly than the first Club of Rome report simulated back in 1972. Global equilibrium would be more rapidly destroyed and our planet exploited even faster than before.

10. The classical ruin of all potentates

Wangling state funding for foolish yet spectacular branches of research, which is what the lobbying body for a technology that has been a lost cause from the outset (namely, fusion energy) has contrived to do, reminds me to a quite extraordinary degree of the 'business policy' of certain medieval alchemists. By promising great things and making constant reference to an always imminent breakthrough in the artificial manufacture of gold from base metals, such chancers repeatedly extracted more and more money from rulers who were already in debt up to their eyeballs.

Incidentally, with regard to the prospects of fusion research, I remember my friend and mentor Henry Margenau, then a famous theoretical physicist at Yale University (and the man who aided my researches into the emergence of biological right-left asymmetry on the basis of asymmetrical beta decay), telling me back in the 1950s that I should not be surprised to find that, in 50 years' time, use of fusion energy was still on the threshold of an 'imminent breakthrough'; the plain fact was, it could never work. It was Margenau who drew my attention at the time to the parallels with (false) alchemists (true alchemists were preoccupied with transforming matter; their goal was self-knowledge, not making money). He used to say that fusion researchers would behave in exactly the same way: arranging to have ever more splendid institutes and ever more costly plants financed for years to come in return for promising governments the earth. We shall come across the same technique in the following discussion of genome research. This brings us to my second example of unacknowledged complexity.

The human genome – another interconnected phenomenon

Headlines like 'Humanity decoded', 'Gene technology to conquer cancer and AIDS', 'Designer humans', 'Prospecting for gold in the genetics lab', 'Book of life lies open', 'Engineering evolution', or 'Creation: the key' sound as if they herald a discovery of millennial importance. However, they are misleading. They also simplify what is basically a very complex process. A certain distance now lies between us and the spring of 2000, when the media acclaimed the 'decoding' of the human genome, and things no longer look quite so sensational. Contrary to the trumpetings of the press and television, while computer scientists have indeed sequenced many of the more than 3 billion letters (base pairs) of the genetic code in the data banks captured by the new methods, the human genome is by no means decoded. It is known, certainly; we can even imagine what it looks like, what its linear arrangement is, but we do not understand it. It is as if the letters of a language has been deciphered, but that does not mean (far from it) that the text can now automatically be read, let alone understood; another dimension is required for that. The way we now visualise the letters of the human genome (forming a linear sequence) leads our interpretation of the code astray.
But even the mapping that has been done up to now is disputed by certain researchers. Biomathematician Samuel Karlin (Stanford University) has shown by comparison with already confirmed code sequences that in connection with the sequencing technique used by Craig Venter (who has been called 'the Bill Gates of genetic research') that a third of genome mapping at most is acceptable, a third contains errors, and the rest, he says, is junk. A confusing jumble, in other words – as if one were asked to assemble a jigsaw puzzle where the pieces had been muddled up with those of other puzzles.

Mapping does not mean understanding

Apart from the fact that the overall mapping process itself is not without its sceptics, it is also the case (and this is the real problem) that the complex functions of even the correctly mapped gene are still wholly obscure. To this day the interplay of the proteins read off from the genes and the way they interact within the organism are not understood. Consequently, many serious scientists now distance themselves from the fuss being made about the alleged decoding of genetic information. This emerged clearly from the heated discussions at the Lindau Nobel Laureates' Meeting held in the summer of 2000.
Furthermore, what is currently being touted as a great discovery is not even all that new. As early as 1969, in a 2-part NDR television series entitled 'A code is deciphered' [*Ein Code wird entschlüsselt*; the subtitles translate as 'Into the heart of living matter' and 'The secret of life'], which was based on the discoveries of Chargaff, Levine, Crick, Watson, and others, I was able to illustrate the structure of spiral DNA and the processes involved in reading the code with the aid of electromicroscopy and animation. What are new (and very impressive) are the techniques now used for sequencing gene segments. However, not even these have resulted in fresh discoveries about the complex mechanisms by which genes control living processes. Cell biologist Günter Blobel (Nobel Prize for Medicine, 1999) also sees in the much-hyped 'decoding' breakthrough a purely (albeit breathtaking) technical advance, since now the sequencing of DNA, once laboriously performed 'by hand', can be done by computers in production-line-type automated plants having a continuous throughput of 1,000 base pairs per second (!). Sir James Black (Nobel Prize for Medicine, 1988) is similarly critical of 'exaggerated reporting' and the 'premature promises' made as regards a future medical application of the findings of genetic research.
To put it plainly, huge though the advance has been in computer-controlled techniques of gene-mapping, the resultant gain in knowledge about how life works has been virtually nil. The fact is, no matter how intelligently one follows the work of the sequencing robots, one is still a million miles away from tracing the complex interplay of living processes. The myth of the 'decoding of our genetic make-up' (when all that has been deciphered is a mangled alphabet – nothing like the intercon-

nected meanings of words, the punctuation, or even the grammar, not to mention the sense of the whole text) lures us only too easily into believing that this glimpse behind the scenes is all we need in order to be able to control living processes better than nature itself. Actually, it is more like a bunch of illiterates seeking to improve texts they cannot even read – and raking in the praise and the astronomical research grants while so doing. This is a view that was shared by the brilliant nucleic acid researcher Erwin Chargaff, who after all made key contributions to the 50-year history of the development of this research sector.

No sign yet of any diseases being healed

As regards curing such typical public-health ailments as cardio-vascular disorders, diabetes, strokes, or asthma, the mapping triumphs of the genetic researchers are insignificant as yet. Even Altzheimer's, cancer, and ageing itself are processes whose origin is always a complex process, resulting from the disturbed interaction of many genes as well as incorporating additional influences from the patient's environment and way of life. Even with the genetic make-up captured in its entirety, none of these ailments can either be predicted more accurately or treated any better. And even where it is possible to assign an altered gene to a particular illness, we know neither what precise variation leads to the illness nor whether that gene alone is involved or others as well. In connection with breast cancer, for instance, first a genetic defect in chromosome 17 was discovered, then also one in chromosome 13. Subsequently it was discovered that only 5 per cent of breast-cancer cases have anything to do with genetic defects, but we do not even know which genes lead to cancer and which do not. So working towards a cure with the genetic data captured hitherto makes little sense and may in fact be dangerous.
Particular caution is called for in connection with any attempt, on the basis of gene mapping, to use viruses as vehicles to smuggle genes in and cure people that way. Gene therapy then becomes a game of Russian roulette. Now that the first deaths have actually occurred, critics of gene therapy to repair an inherited defect or replace a damaged gene by one that is intact consider it too risky for the time being and at best ineffective. So using the prospect of more effective gene therapies to extort more funding for stem-cell research is in the highest degree immoral.

Targeted improvement of genetic material is an impossibility

With all the focus on mapping, questions of cybernetics and hence of the complexity of genetic processes continue to go unanswered. The fear that people might nevertheless, using genetic manipulation, try to exploit the little knowledge available to intervene in the natural evolution of the human race is one that also found expression at the aforementioned Lindau Nobel Laureates' Meeting.
Werner Bartens, in his outstanding book 'The gene tyranny' [*Die Tyrannei der Gene,* 1999], bewails the lack of knowledge among gene technicians about the interplay of processes in molecular biology (for example, regarding the complex action involved in genes being switched on and off by repression and induction), which is why they are still hoping that one day they will be able to overcome even the massive errors associated with cloning. They appear not to realise that altering one gene changes not only a specific function but the way in which all genes relate to one another. It is as with a text, where the additional of a single word (even a single new letter) can completely change the meaning. With a text, though, once it exists and the letters are known, you can at least read it, and you can do so even if you don't understand the language. The way information is passed on within the cell is far more complicated. Even if the individual letters (the base pairs) of the DNA had been arranged in a line sequentially and the words (amino acids) and sentences (proteins) they represent had been determined precisely, it would still not be possible to say which should be read and complied with when, nor what their effect was on other 'words' and 'sentences', particularly in view of the fact that each new division brought fresh variations into play.
Added to which, DNA as sequencing researchers describe it (namely, as a linear chain) is never present as such in its active form. Like the chromosome set, which is visible only temporarily during cell division, DNA normally forms a jumble. As a result, sections of the chain lying some distance apart may in fact fall next to one another and interact. So no conclusions whatsoever can be drawn from the chain drawn out in a line as to which genes cooperate with which others, using which proteins, and why and when which genes unravel during the copying process or not. The secret of a gene's role lies neither in the gene itself nor in any

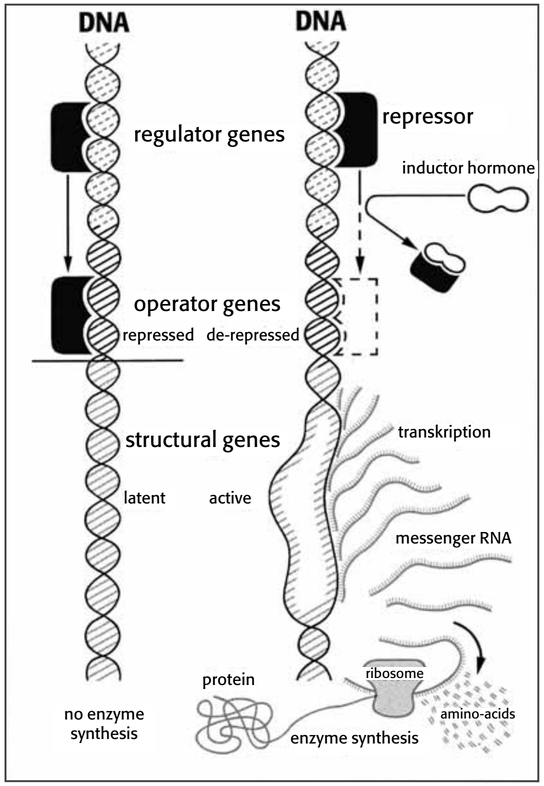


fig. 35: **Transfer of genetic information to the 'operation' of the cell**
The diagram shows the complicated process (subject to multiple checks) of transition from a state of rest in a specific cell function to its activation. The constantly complex interplay between transcription inhibition and its removal is here portrayed in a much-simplified fashion.
Left: A strand of DNA comprises sections performing very different roles. For instance, regulator genes, which for the purpose of regulating protein or enzyme synthesis send so-called 'repressors' (usually basic proteins, e.g. histone) to specific operator genes, in order to prevent the latter from passing on, without instruction, the enzyme-synthesis order to the structural genes subordinate to them. Such synthesis does not occur – unless, that is, an inductor (usually a hormone) removes the repressor, as in the right-hand section of the diagram.
Right: The no longer suppressed section of the operator gene is able to pass on the transcription ('information-transfer') order of the structural gene assigned to it. With the aid of a special nucleic acid called 'messenger RNA', which takes on the code it has read, what now happens is that in the ribosomes (which are like netting machines) the protein molecule corresponding to the code is built up from individual amino-acids, with this end-product often, in a negative feedback loop, bringing the whole process to a further halt, i.e. providing renewed repression.

examination, no matter how thorough, of its structure or of its immediate environment but in the pattern of its interaction with all other genes and everything else that happens in the cell nucleus. Recent work on simulating the interconnected processes taking place within a single cell, as illustrated by the metabolism chart reproduced here (see fig. 33), wrestles with the extreme complexity of such events (one example being the fact that each of the thousands of enzymes is influenced not only by its own product but also by many other substances of the cellular network). Moreover, as we saw in the previous chapter, the switching on and off by means of infiltrated substances operates in both directions. According to Wolfgang Wiechert of [Germany's] Siegen University, the only way to get on top of the complexity of such simulation models is by drawing a sensible balance between the large number of unknown parameters and the small amount of measurement data available, particularly since the behaviour of each individual cell itself depends on its place in the cell group. And all this is in a state of constant interaction with a network of genetic regulation that we know only fragmentarily.

It's not the sequence of genes but their pattern that we need to understand

So merely sequencing genes will not be of much help to us if we are ever to understand the full complexity laid down in a cell's genetic make-up, even if a hundred or so institutes around the world, many with 20-strong teams and impressive amounts of material and financial backup, continue to work on uncovering the rest of the chain of letters underlying this basically magnificent text. Certainly the pretensions aspired to out of the present state of knowledge are grossly excessive.

Manipulating a gene to any purpose and controlling the overall effect created in a purposeful way simply cannot be done, if only because life is played out not in DNA but in umpteen thousand proteins that in a complicated process of translation emerge in conformity with DNA building plans. Of those, our chromosomes contain at least as many as DNA itself. Regulator genes, operator genes, and structural genes, working together in harness with RNA (which translates the code), histones (proteins, which impede this), and activating hormones (which uncover latent texts), by switching different pieces of information on

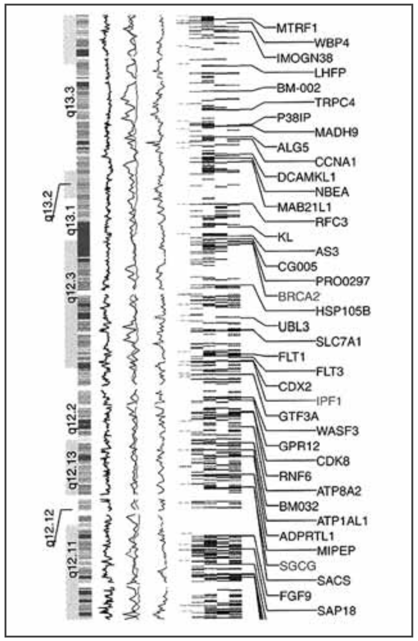


fig. 36: **Chromosome 13**
Section from genome sequence of one of the smaller human chromosomes. The ca. 8 million base pairs of this tiny fragment of DNA contain the information needed to synthesise more than 40 different proteins. On this scale, the total genetic material of a cell that controls some 12,000 proteins would be over 70 feet long.

and off, exercise very different but nevertheless closely interwoven functions. In accordance with those functions, proteins fold themselves in specific ways and themselves interact both with one another and with the genes. It follows that the complexity of living processes can be understood much more readily through the pattern of these transcription processes (i.e. translation from the language of DNA to the language of proteins) and how they are controlled than through a simple counting of genes. In this connection Budapest evolutionary biologist Eörs Szathmary suggests that the genome counters at last start thinking in terms of the complex networks of gene regulation and employing equations the way ecologists use them for the multiple interactions that occur within food networks.

Cloning = incest squared

A word about the cloning of 'pre-programmed' living beings. Since the copying of genetic segments plays an important role as a recombination procedure in connection with deciphering the code, such experiments have long formed part of the repertoire of the genetic researcher. Cloning in cell cultures and the production of chimeras (between a mouse and a human, for instance), the arousal of sleeping information (as with the axolotl, a primarily aquatic amphibian that as a result of receiving additional hormones turned into a land animal that is now extinct) are things I wrote about back in 1974 in my book 'The cybernetic age' [*Das kybernetische Zeitalter*] under such chapter-headings as 'Genetic Babylon' or 'The dubious homunculus'.

The universality (already hinted at here) of the genetic code for the whole living world (as a result of which we are related not only to the monkey and the mouse but also to worms, grasses, and bacteria) also accounts for the large number of unused and often repeated sequences in our present genome. The fact is, it seems that somehow or other, at least fragmentarily, the human genome contains in latent form the whole of the evolution we have gone through – including, in other words, the genetic information relating to past and probably also future life forms. It would be an unforgivable mistake if were to break down the species barrier with which nature has (despite this universal interrelatedness) protected the individuality of each life form up to now by indulging in reproductive and hence irreversible cloning.

The fact is, we still do not know (beyond the long-familiar step of transcribing and thereby controlling the regulator, operator, and structural genes) how and why genes lead, in combination with other cell parts such as RNA, ribosomes, and enzymes, to a living organism and its self-regulating functions; nor shall we ever make any more progress here, no matter how precisely we study gene segments and their sequences. So cloning of living beings will only ever be accomplished with a very high proportion of errors. Certainly nowadays, whenever cloning is performed, deformities are the rule. Nearly all animals copied up to now have defects in their genetic make-up. Most of them die before parturition; many develop abnormalities. Don't forget: the much-hyped presentation of Dolly the cloned sheep in 1996 was achieved only after a total of 277 monstrosities and stillbirths. Rudolph Jaenisch referred in his work at MIT to the fact that many cloned mouse embryos exhibit false coining patterns in their genes, some of which (in mice that survive) appear only later. Such defects would occur if human beings were cloned and might lead not to the death of the embryo but to subsequent serious damage in the child or the adult.

The reasons are obvious: in every attempt to duplicate living beings, the evolutionary random generator comes into play. Each time a copy is made, abrupt make-up changes (mutations) occur in the regulator and operator genes. Cloning has the effect of multiplying such defects.

A further shortcoming is that the symbiosis with the mitochondria (the cell's respiratory particles) that is of such vital importance for each body

cell does not start up after cloning, because mitochondria and their specific genetic make-up are not passed on in the cloning process. Cloning thus becomes a licence for any kind of cancerous growth, the principle controller of which is the respiratory chain of the mitochondria (in competition with the glycolysis of the cancer cells). Not even Herbert Markl (a proponent of gene technology) is at all sure 'whether embryonic stem cells cannot for their part lead to pathological developments – cancerous degeneration, for instance; in fact, he regards the Franco-German proposal before the United Nations for an international ban on reproductive cloning as a matter of extreme urgency (in an analogy with the cloning of living beings, he mockingly alludes to the media circus surrounding the subject in terms of 'an inexhaustible cloning of news').
But even were cloning to succeed in producing a viable living being in the first generation, it is probable that in subsequent generations the many defects in each chromosome set that normally get repeatedly 'Mendeled out' (as we say in German) by crossing with different genetic material and by heterosexual reproduction would be perpetuated, becoming more marked with each further step. Children of close relatives already show genetic damage (hence the incest taboo in all cultures), and this would certainly happen in the case of children cloned from a single individual, with the result that instead of there being a positive selection of genetic material this would quickly become denatured.
However, because of the complexity of the process involved, basically the vision of cloned supermen alarms me much less than the use of genetically manipulated types of tomato, maize, or rape, which could after all provoke the biological collapse of entire ecosystems. Once they are released, how things develop further will be out of our hands. The cloning of a human being, on the other hand, is likely to be a one-off process that (should it succeed) would in all probability soon expose the imponderables of such a development and turn out to be a path that could not be followed for long.

Transplantable organs from embryonic stem cells are an absurdity

Embryonic stem cells emerge in the first stages of division, once seed and egg have merged. They constitute the earliest still undifferentiated life. So if we cannot, through the cloning process, use them to design an entire human being, can they perhaps be used at least to develop organs that can be transplanted? Conglomerates of liver, kidney, or brain cells from a Petri dish, for which no donor need be found? Certainly Australian Peter Mountford (famous for having been awarded, in 1994, the first patent for isolating embryonic stem cells for the purpose of manufacturing genetically modified animals) has great hopes of therapeutic cloning 'to alleviate human suffering'. What he fails to mention is that these as yet undifferentiated cells are more likely to develop cancer in a body than impart the 'beneficial effect' he hopes for – if, that is, they are not rejected altogether. The fact is, the reason why people want to breed tissues and organs from stem cells is that they are 'all-rounders'. But that is precisely the danger.
Cancer cells, too, are in a sense undifferentiated all-rounders; they may once have been differentiated into skin cells, say, or intestinal cells, but they have reverted to the embryonic stage and no longer obey the signals of the organism. Having originally belonged to the organism, they are not at first recognised immunologically as foreign cells.
Once again, then, the gene technicians have made exaggerated promises. So far, at least, not a single condition has been healed with embryonic stem cells. Scientists from several faculties at Bonn University therefore wrote their own manifesto rejecting research projects using human embryonic stem cells to manufacture replacement tissue for treating brain disease and other hereditary disorders. The funds, they reckoned, could be used elsewhere in medicine with far greater prospects of success.
I cannot help agreeing with them. With the cloning of organs, the potential of a germ cell (which after all carries the development of an entire human within it) is channelled in the direction of a single organ; the impetus of a complete human being is pruned back, as it were, in order to form a liver or kidney or brain 'monstrosity'. Another horrible idea, not to mention the fact that, as we have seen, a subsequent cancerous development is programmed in to the organ concerned. Accordingly, a refusal to use embryonic stem cells should be welcomed – and not just for ethical reasons.
So why not forget about undifferentiated germ cells and use adult stem cells instead? Is it because these are already too differentiated? But precisely that seems to me irrelevant - indeed, a positive advantage. The fact

is, healthy liver tissue has already been built up using liver stem cells, blood using bone-marrow cells, and soon it will clearly also be possible to build up new muscle tissue in the heart by injecting stem cells from the same patient. Certainly, cell cultures of every kind of healthy and diseased tissue have for centuries formed part of the arsenal of research.
But beyond the cultivation of fresh tissue (in other words, so far as cultivating entire organs is concerned), prospects look bleak. Complete internal organs are too complex to be reproduced by aggregates of cells and vessels. For a long time to come, therefore, transplantation using donated organs will be simpler than cultivating fully-functional internal organs.

The emperor's new clothes

We face the phenomenon that, because of the floating of excessive hopes, a specialist area of science in which people have been working successfully for more than 50 years has suddenly been placed on a pedestal as if it were in a position to eliminate such scourges of humanity as cancer, Alzheimer's disease, and gene defects. Promoting genetic technology has become associated with the kind of appeal to human compassion that none of our politicians has felt able to duck. Again I must draw a comparison with those medieval alchemists, who as experts in the smelting and dissolving of metals led their rulers to believe that they would one day be able to transform lead into gold.
As with them (and with the instances we were looking at in the field of energy such as fusion and the fast breeder), so with genetic research: this is mainly about the allocation of research money. Once again, the lobby has been successful. German Chancellor Schröder said he was backing biotechnology so generously (1.5 billion marks for genetic research alone) ' because it guarantees prosperity and jobs' (!). It's the old story of the emperor's new clothes. And the longer the words used in academic jargon, the easier it is to gloss over weaknesses in such plans.
Australian biotechnologist Maxime Paris speaks for many serious scientists when he is sharply critical of what he calls the 'bubble-blowing' of genetic researchers whose 'dominant concern is with doing deals, not practising science. They claim to have access to major discoveries, but they talk about a data throughput 10 times greater than they achieve, and they announce any number of patents.' The measured comments of President Hubert Markl at the last Max Planck Forum on Genome Research in Munich can therefore be seen as a sort of 'profit warning' for biotechnological research, which now has to show what it is going to give humanity in return for the 1.5 billion marks granted. It would be well advised, now, to lower expectations somewhat, particularly since some of the announcements made about the potential of genetic research have been so dishonest as to threaten to bring genetic research itself into disrepute.
Back to the cybernetics of normal living processes. Why allow a patient to continue in what for him/her is an unhealthy way of life and combat the damage with more and more new drugs or even operations on his/her genetic make-up (our common genotype), an approach that has in any case become prohibitively expensive, instead of giving that patient early support on the road to prevention, which because of the way it mobilises the body's own self-healing forces is not only free of charge but also, by making an active contribution towards maintaining physical wellbeing, strengthens mental health as well. The need for a cybernetic approach to medicine (not only for therapeutic but also for social reasons and on grounds of cost) is of crucial importance as regards the future orientation of our society, and it will be taken up again in the final chapter of this book.
But it still happens all too frequently that cybernetic solutions, if they diverge from the opinion of the currently dominant high priests of research, are suppressed by the very same institutions as fall for worthless promises. It is a practice I came to feel the edge of personally when my own immunological investigations were choked off by the German Research Foundation and the Max Planck Society at the instigation of the Heidelberg-based German Cancer Research Centre (dominating the stage at that time was the then 'high priest of cancer', K.H. Bauer, with his dogmatic 'steel and radiation therapy' [*Stahl- und Strahltherapie*], which denied any kind of immune effect). That cancer can be fought only by means of surgery and radiation and has nothing to do with the patient's immune status may be true of a few special tumours. However, the fact that most types of cancer, notably the formation of metastases, most certainly do have an immunological and psychosomatic component and invite relevant therapies was then strictly taboo.

It has taken 30 years for the investigation of the cancer-inhibiting basic proteins first isolated from mistletoe by my team in 1969 (they stimulate the immunological effect of the thymus gland and hence the body's own defences against tumour cells) to be taken up again by German and American research projects, the reason being that such a regulatory effect is now compatible with what has come to be generally recognised as the immunological aspect of cancer.

Just as for the human organism, the same cybernetic approach is now deemed valid as regards keeping our food sources healthy, which means protecting our plants and animals against pests and attack by disease. I hardly need sing the praises here of the agrarian revolution (proclaimed to such excellent media effect in the wake of the BSE crisis) in the direction of ecological arable farming and species-appropriate animal husbandry. Only to make this point: our food supplies are predicated on a living soil that as a complex biotope of plants and animals offers healthy development in that it can easily be steered in the desired direction by harnessing natural feedback loops. This, God knows, will be cheaper and more sustainable as regards a high-value yield than a fundamentally blind process of manipulation using genetic intervention and the associated disturbance if not destruction of the rest of the ecosystem with even more powerful doses of herbicide and high-performance drugs than before. Which brings me to my third example of the importance of recognising complex interconnections.

Genetically modified food to combat hunger in the world

One of the most contentious subjects of our time is genetic manipulation (already well under way) in the cultivation of food plants. Here again it seems to me that, no matter how thoroughly our scientists weigh up the individual influences and effects resulting from the changes introduced by gene technology, we are in no position even to begin to grasp the overall context – namely, the associated indirect effects, chains of effect, networks of effect, and repercussions. And not just in the spheres originally affected, either (a genetically modified food plant together with its biotope, for instance); also in terms of its interdependence with all the other spheres of life, including human health.

That kind of systemic examination has never been undertaken, notwithstanding the potential scope of this first and hence very dodgy human venture into intervening in the natural structure of our ecosystem. Without recognising the wider connections that go beyond the individual discipline (both to negative and to positive effect), given the complexity of the systems concerned genetic intervention in the fabric of nature is ultimately inadmissible – for the reason that a modified genotype, once released into nature, will trigger (by way of reproduction or other mechanisms of self-multiplication beyond the first generation) an autonomous process of transmission and perpetuation that may lead to chain reactions or intensifications that can no longer be controlled. So an irreversible release of genetically modified plants will possibly, in the light of the infinity of long-term risks involved, create problems for which future generations will have to carry the can. The parallels with the 'release' of radioactive waste (which can never be changed back into its former state) implicit in acceptance of the dubious blessings of nuclear energy will be obvious.

All the more astounding, then (the only possible explanation is a bewildering degree of ignorance), is the carefree manner in which new types of genetic pattern are being introduced into existing biotopes. According to figures provided by the German Association of Biotechnology Industries [*Deutsche Industrievereinigung Biotechnologie or DIB*], 90 genetically modified type of plant have already been licensed somewhere in the world. None of them, however, has so far supplied better yields than its natural source plant. The aim of such manipulations is clear: enhanced resistance (particularly herbicide resistance) in the plants treated, which makes them interesting to the agrarian industry because of the increased use of pesticides that they make possible. Consequently, new genetic designs are being placed in the environment to which neither the soil micro-organisms, nor the accompanying plants, algae, lichens, and fungi, nor the worms, beetles, spiders and all the other things that make up each plant's immediate environment have built up a relationship and therefore developed reactions that can be predicted. Unexpected resistances to new pathogens, shifts in the pest spectrum, and unprecedented susceptibilities may well ensue – all necessitating fresh genetic manipulations.

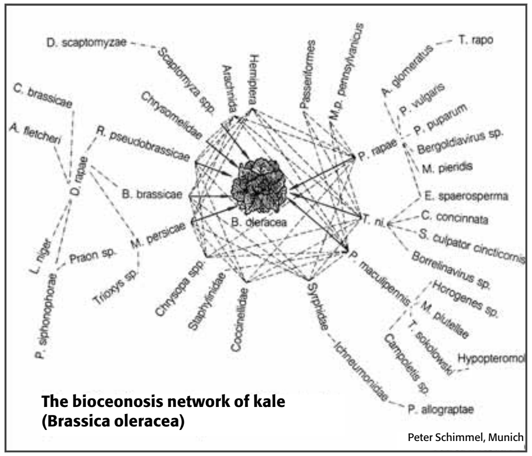


fig. 37: Even a simple cabbage is interwoven in an invisible network with many other species; it forms part of a complex, a system. In the case of kale (Brassica oleracea), we are led to a grand total of 38 other species: insects, spores, fungi, symbiotic seeds and lichens, leaf beetles, syrphids, moths, and spiders that, through a series of interconnected feedback loops, affect one another as well as the development of the cabbage all play a part in that system, as do weeds, animals that live in soil, and various micro-organisms. Even the 'harmful' caterpillar of the cabbage white butterfly performs important functions for the whole, providing food for the ichneumon fly – on which in turn other limbs of the network depend. Possibly the harm done by many so-called 'pests' and 'weeds' lies more in the fact that they require spraying with insecticides and herbicides, which then bring about the collapse of such a biocoenosis, together with its protective function. After that the economically useful plant being cultivated, isolated from its environment, can be protected only with 'hard bandaging'. If at some time in the future genetically-modified insects are then let loose on the biocoenoses that still work and chaos results, the bill for such a destabilised agriculture will no doubt turn out to be prohibitively expensive.

A uniform genetic pattern means not only an undoubtedly higher level of productivity (at the same time as greater susceptibility, as with all monocultures) but also elimination of the biological random generator, the role of which (in regulating evolution, for instance) is still almost wholly obscure. The failure of the 'Green Revolution' in many developing countries (which within a short period turned Kenya, for instance, from a cereal-exporting country into an importing country) should have come as a warning. But beyond that, each genetic restriction also means a lessening of the spread of a species, so crucial for survival. And of course the same will be true of the human species if the gene pool is restricted to properties that may for the moment look desirable, as we saw above.

Health repercussions

But it is not only the complexity of the interactions between plants, soil, small living beings, and micro-organisms that have escaped examination; not the slightest attention has been devoted to how the human organism will react to the altered metabolism and new types of content in genetically modified plants. Quite apart from the afore-mentioned increased use of herbicides, to which the genetically modified culture plants may well have become more resistant but certainly not our organism, we have to ask ourselves whether, as well as the desired effects, slipping in isolated genes from a different species, will not also trigger fresh types of allergy among consumers – in other words, immunological reactions on the part of the organism. We must expect to encounter (with increasing frequency) cases of metabolic disturbances, changes in intestinal bacteria, and digestive incompatibilities, not to mention more profound, long-term damage. For instance, Paris's Pasteur Institute has now clearly shown that resistance to antibiotics can be transferred from GM maize to animals and humans. So it not without reason that GM food is provoking widespread unease.

Maybe many of these things will not in fact occur. However, there is certainly a risk. I myself, many years ago, worked with zoologist Fritz Anders on gene-specific crossing of plants (*Nicotiana*) and also of certain fish species (*Xiphophorus, Platipoecilus, etc.*). We performed biochemical investigations and did research into proteins acting on genes via mechanisms of induction and repression. Even back then it was clear that, when we transferred a gene, what was transferred was not simply an inherited characteristic that we just happened to recognise; the whole pattern of the genetic text was altered as a result (the relationships, if you like, between each gene and every other), and a series of latent, sometimes recessive combination effects (including tumours) occurred that might have nothing to do with the effect desired. And studying such links was not even our objective at the time. I mention this purely in order to draw attention to the complexity of any genetic intervention, particularly when this does not result from 'normal' interbreeding.

Not all biotechnology is the same

What would be regrettable in this whole discussion would be if the baby were to be thrown out with the bathwater. Unfortunately everything to do with interbreeding, new breeds, biotechnology, and so on gets thrown into the same pot as genetic manipulation (not least by the protagonists of gene technology themselves with a view, by making such comparisons, to highlighting its harmlessness). But particularly industrial microbiology and the huge gains we are able to harness from biotechnology with regard to ecological production processes (far too little of this has been done up to now) get tarred with the same brush. Without biotechnology we should have no beer, no yoghurt, no cheese, and no yeast cakes. And such forward-looking processes of industrial microbiology as the extraction of biogas, energy-free ore preparation (largely already the case with, for instance, bacterial copper-extraction), and other environment-friendly biotechniques would never have arisen. Lest we spoil anything here, it seems to me that we need urgently to draw a strict line between those biotechnologies that are compatible with the environment, with their enormously advantageous potential, and those that are incompatible because they make irreversible changes to the universal genetic code.

As regards the latter, I am amazed by the almost fanatical determination to win acceptance demonstrated by manipulations that, after all, we do not even begin to understand. Why is this so? We have some 400,000 plant species in the world, only a fraction of which have ever been studied in terms of the role they might play in nutrition (as well as in providing a 'green pharmacopoeia') and out of which a total of perhaps 10 species cover 99 per cent of the world's vegetable food needs! There is huge natural potential lying fallow here, potential that could be exploited in harmony with the ecosystems and biotypes in which it is embedded.

Science needs public consensus

One hopes people will gradually come to recognise that not every invention or development should be taken up or applied if harmful or even simply unknown consequences (in the use of GM seeds, for instance, or in connection with the mishaps that have dogged gene therapy up to now) begin to become apparent. It may be that a problem can be solved in this way, but a whole series of fresh problems may spring into existence as a result.

It is not merely exaggerations and false promises that concern the public; so too do obstructions and hindrances. The promotion of science is a somewhat two-faced process: on the one hand groundless promises receive support and falsifications are covered up; on the other hand it happens all too frequently that research projects bucking the currently reigning dogma (as our cancer-inhibiting proteins did) are blocked by the selfsame institutions and their experts. 'Science must show its credentials; it has no license to improve the world,' German MP Michael Müller once wrote in [the German weekly] *Die Zeit*. So when changes of scientific course occur in future, they must be set on the basis of higher decisions that will clearly need to be debated in public; such decisions can neither be left to chance nor taken by scientific bodies alone. The fact is, no specialist discipline can decide on its own account how important it actually is to science or society. On other words, ordinary citizens and hence also politics will in future have to have a larger and larger say. As consumers, they already do. Unease about GM foods and the disgust that many people feel about them, whether rightly or wrongly, are nevertheless real and have led companies like Monsanto to sound (albeit hesitantly as yet) the retreat on this tricky terrain.

So I see it as a social duty for researchers to end the disturbed relationship with the public that has resulted from the genome rumpus and tell people more about what is really happening in their laboratories instead of hiding behind a smoke-screen of jargon to make their findings sound more significant than they actually are.

The sobering fact is that, as regards deciphering the genetic code, not a lot has happened since Chargaff, Crick, and Watson discovered the double helix as bearer of life's genetic make-up; in terms of knowledge about the genome's complex reading processes and the events this triggers in the organism, little new knowledge has been acquired. What is new about the whole business is the way in which it is marketed: on the one hand inflated (but quite unsupported) healing prospects are held out to suffering humanity; on the other hand, science fiction scenarios (with a dose of Frankenstinian horror thrown in) are used to wangle vast subsidies out of governments and other donors. A clever PR concoction has produced an explosive expectation that all three prospects (abolition of world hunger, gene therapy, and the cloning of the future Superman) are but a step away. One is reminded of the well-known dictum of Manfred Eigen (Nobel Prize for Chemistry, 1967): 'Conditions in the world will improve not as a result of genetic changes – only through more brain.'

Recognising complexity

All this begs the question: how can our brains open up to recognise complex processes? The answer, as with anything that can be learned, is: through practice. I have called the following chapter 'Systemically appropriate planning and action', and in it I shall be looking in greater detail at a series of cybernetic aids and rules that will help us to throw off the hesitancy about dealing with complex bodies of information that we have brought upon ourselves through our habit of linear thinking. I shall also be suggesting ways in which bodies of detailed information can be arranged in a pattern, enabling us to sense and understand the cybernetics that inform them.

First, however, I want us to gain a better understanding of our three examples and our failure to recognise their complexity; to do this I refer back once again to the computer image of Abraham Lincoln that constitutes our fig. 5. Just as in that representation it makes no sense to examine in more detail the individual squares, their degree of greyness, and the order in which they occur, it makes equally little sense (sticking with the example of gene technology) to try to describe the gene sequences present in chromosomes in greater and greater detail, particularly since in any case fresh variations appear at each stage of division. Because as with the squaring of the Lincoln portrait, here too it is in the pattern of interactions between one gene and all the rest that we shall find the secret of this particular gene's special role, not in a study (however precise) of its structure or immediate surroundings,

But complex processes take place on a wholly different observational level and in a different dimension than proceeds from the individual element of a system. In addition, as decoded by the 'sequence mappers', DNA in its active form never exists anyway. In the words of Werner Bartens, in terms of its real action (not in the lab, that is to say) it is 'so entangled in a genetic dog's breakfast of billions of base pairs that interactions occur with segments lying far away along the chain'. For that reason alone it would be impossible to make any deduction whatsoever, from stretching the chain out in a line, as to which genes cooperate with which others or which genes unfold during the reading process and which do not. Just as we shall never, in the case of the Lincoln image, learn from an elaborate set of tables detailing ascending shades of grey that the pattern represents a human head. Only through the interaction of the different squares do curves form and proportions emerge in such a way that eyes, ear, and nose become recognisable. If the aim is receiving this 'message', then studying individual squares is (scientifically speaking) the wrong way to go about it. Only by chance will this afford the odd 'glimpse of truth'. It follows that, as regards dealing with the complexity of living processes, the depiction in fig. 33 of certain feedback loops and how they are controlled by enzyme interaction offers a far better 'way in' than (unfortunately, but it has to be said) we are currently being offered at such enormous expense. This is a fact with which the teams involved in genetic research must themselves come to terms as they work on elucidating and sequencing the billions of text segments that make up the universal code.

9 • Systemically appropriate planning and action

What is cybernetics?

In this chapter I want to go into rather more detail about cybernetics itself. By cybernetics (from the Greek kybernetes, 'steersman') we understand the perception, control (steering), and self-regulation of interconnected processes with minimal expenditure of energy. Apt as the term is for new intellectual models, it has often been equated with control technology and computer guidance (though nothing could be more non-cybernetic than the way a computer works), with the result that it is frequently misunderstood. For this reason, we should do better to speak of 'biocybernetics'. Even according to its founder, mathematician Norbert WIENER, cybernetics has its true origin in the world of living matter, not in that of computers. Of its nature it has nothing to do with robots or electronic calculating machines but with the kind of genetic control that occurs in our cells, with regulation by enzymes and hormones; it is about a baby's first steps.

The arena in which cybernetics has always operated is in what happens biologically, and there it does not at all imply detailed pre-programming or central control (don't forget: the steersman is part of the system); it means simply providing impulses towards self-regulation, 'touching off' interactions between individual and environment, stabilising systems and organisms through flexibility, making use of existing forces and energies, and constantly interacting with them. It is through fluctuation, not rigidity, that this process came to underpin life; this is how nature gained its unflagging strength and stability.

It is this special organisation of all living systems that enables them to structure the course of events between their individual parts in such a way as to keep them going and control them automatically. This is achieved mainly through the stabilising dynamics of a network of feedback controls that, interwoven with other feedback loops and subdivided into partial feedback controls, basically sustains every organism, all the way from individual microbes, via human beings and part of the artificial systems created by human beings, to the biosphere as a whole.

Every feedback loop (see fig. 4) consists in essence of 2 things: the quantity to be controlled (we call this the control quantity) and the control itself, capable of altering the former. The control uses a sensor to measure the state of the control quantity. If a disruptive factor has altered that state, the control issues an appropriate instruction (the adjustment value) to an adjusting element, which then removes the disruption by way of a suitable adjusting factor, adding or taking away an appropriate exchange factor. In this way the system to be regulated is 'fed back' to itself. The disruptive factor and the exchange factor of course constitute links with the outside world.

Positive and negative feedback control

If the sensor registers too high a value, this will be lowered by the actuator or adjusting element. If the value is too low, it will be raised. That is why, in connection with such self-regulation, we speak of 'negative' (reverse) feedback. Were feedback to operate in the same direction, a value that had changed upwards would be further boosted by the control and we should have positive (same-sense) feedback. Far from enjoying a regulatory cycle, the system would start rocking violently in the direction taken and would either explode or freeze up. Nevertheless, positive feedback controls are necessary; they represent the 'engines' of a system, setting things in motion in the first place or throttling them down completely.

Metamorphoses, too, as when a caterpillar turns into a butterfly, and other evolutionary processes require positive feedback on a temporary basis in order get out of a former state of equilibrium and into a new one. Ultimately, however, they still have to obey the superordinate negative feedback control system. If they do not, veritable 'sorcerer's apprentice' situations may arise (in either direction) that cannot be brought back under control. This is why no viable living system exists that does not have a system of negative feedback control.

Interconnected feedback control systems

However, the control itself also takes its cue (whether because we set it in advance or because it is linked up to other systems) from a command variable that is superior to itself and pre-determines the target value for the control variable. The target value may in turn go up and down because, for example, it is itself the control variable of a different regulatory cycle. That control variable may for its part be the actuator of a third regulatory cycle and this, taken as a whole, may be the disturbance variable of another. In reality, then, there is no such thing as an isolated, self-sufficient regulatory cycle but only ever mutually entwined, open systems with a number of interconnected feedback controls, the target values of which depend on one another.

Unfortunately, knowing how a system is interconnected is not the whole story. Because the crucially important thing is not only *what* is connected *with what* but also *how* it is connected – in other words, knowing the strength, nature, and direction of the interactions between parts. Those interactions are not only very different, not merely either positive or negative, strong or weak, but even for the most part non-linear, which is to say that their strength and even their character may vary over time; they may suddenly switch from support to destruction and in association with other effects produce quite new combinations. As a result, each effect between two systems has its own dynamics, which can be expressed in terms of mathematical functions. There are connections with linear effects and others having non-linear effects. Some connections are of a higher order (with threshold values and limits, say, or fluctuating and tipping effects) while others incorporate time delays; there are also complex connections such as interconnected feedback control systems in which now negative, now positive feedback loops dominate.

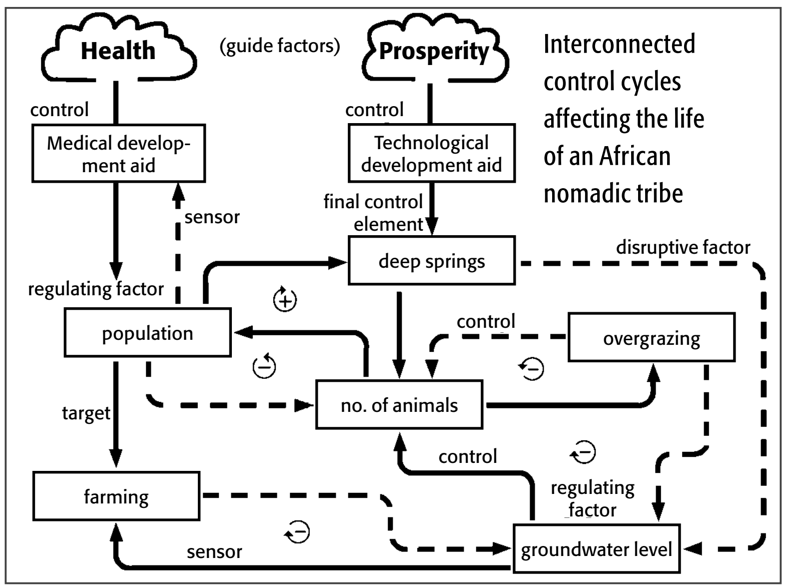


fig. 38: Example from development aid of the way several control cycles intersect

This brief overview, coupled with the excursion into bionics in the previous chapter, is intended to show how rewarding it might be for our own economies, too, rather than pursuing a linear development of existing product ranges, occasionally to give some thought to the biocybernetic principles underlying them. If we wish to reset our priorities for systemically appropriate planning and action, we need to keep the biocybernetic status of complex systems constantly in view. So, for example, appraisal on the basis of the following biocybernetic ground rules is the first and at the same time final step in a planning procedure conducted with the aid of the Sensitivity Model. This will constitute an evaluation in terms of the criteria of viability and thus represent goal-setting and review simultaneously.

The eight basic rules of biocybernetics

The criterion of viability is based on eight rules; complying with these, coupled with interconnected thinking, will already help to avoid major planning errors. Merely taking them into account will allow fresh ideas to emerge, making it easier to reassess a system with regard to solving problems within it. Applying them will help any project to achieve a greater degree of 'cybernetic maturity' and will offer solid arguments in favour of implementing things that are systemically compatible and therefore appropriate to human common sense. These basic rules, which I first formulated in connection with a UNESCO study a quarter of a century ago, are not something invented; they are copied from nature. They should be seen not so much as prohibitions, more as prods in the direction of innovation. As such, they constitute a sort of checklist for a successful management strategy. I have already dealt with them in several of my publications, but it is essential that I set them out here as a constituent of the working aids I shall be discussing later in this study.

Rule 1

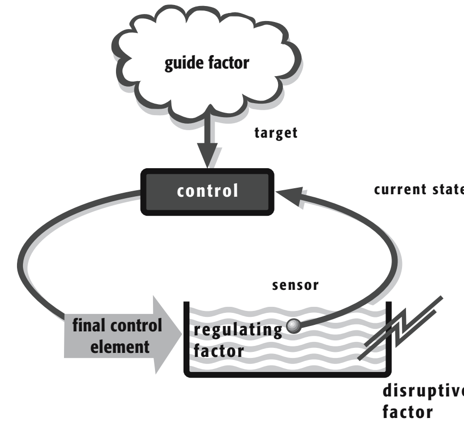
Negative feedback must dominate over positive feedback.

Positive feedback sets things in motion through self-reinforcement. Negative feedback then ensures stability against disruptions and excesses.

Negative feedback implies self-regulation through circular processes. Examples are the control of hormone concentration by our autonomic nervous system, regulation of the supply of petrol by the carburettor float, the way a centrifugal governor works, the interaction of supply and demand, the well known 'pig cycle' and 'potato cycle' resulting from oversteering and cyclical growth, or the maintenance of ecological balances between animal and plant species.

Whenever I am explaining this, I like to drawn on the example of predator (wolf) and prey (hare), where body weight, running speed, and kill frequency constitute a feedback loop. The faster a wolf runs, the more hares it is able to catch. The more hares it catches, the fatter it becomes, ergo the slower it can run, the fewer hares it can catch, and the thinner it becomes again, ergo the faster it is able to run again, the more hares it is able to catch again, the fatter it becomes once more, and so on and so forth. This regulatory cycle is itself entangled with others – e.g. that between the size of the hare population and the resources on which it can draw, namely the plant larder available.

Self-regulation is the most important organisational principle of a partial system, as soon as it seeks to survive within the overall system. Here I touch on the true complexity of open systems and the fact that in these the very steersman is involved; because the open system's regulatory cycle itself is simply a component of a larger, interconnected effect structure.



As we become more familiar with regulatory cycles, our 'inside-out' view of reality starts to change with the addition of a further element: causality loses its established direction since cause and effect fade into each other. They gradually switch roles in the circular process; each cause itself becomes an effect, and each effect in turn becomes a cause. Until we become aware of this fact, the finger of blame will go on being pointed, be it within marriage, between parents and children, or in political conflicts such as those between Turks and Kurds, in Kosovo, or in Israel. The fact is, a sustainable solution can be found only at the systemic level.

But it is not only cause and effect that become relativised; normally solid assessments such as the criteria of progress we have been talking about take on a new significance when they are seen as interconnected within a system; in fact, their significance may even be reversed. Take the well-known Darwinian thesis of 'the survival of the fittest'. According to this 'faster', 'larger', 'stronger' would be an advantage for every living being. For some, that may be the case, but for others it is not, or at least only momentarily, just as an artificially inflated 'shareholder value' is no guarantee of survival, indeed may even imperil survival in the long term.

Here too there is an example from the systemis dynamics between predator and prey. A lion runs at around 50 kph, but for several seconds it can attain as much as 70 kph; its prey, on the other hand, an antelope or a gazelle, can run at 80 kph for minutes on end. Tough on the lion, you say? On that contrary, that is why lions still exist! If lions were faster than their prey or did not have to abandon a long chase for lack of energy, they would have consumed their food resource long ago and would have died out. That is what must have happened to the sabre-toothed tiger, whose stay in this earth was only a short one because its huge teeth never let prey escape, its population rose accordingly, and its resources were increasingly unable to

recover. Because the immediate feedback loop was interrupted, the superordinate feedback loop came into play and the species was eliminated.
So Darwin's thesis is usually misunderstood: it is not the fittest in certain classes of performance that survive but the fittest in terms of interplay with the system. It may be worth thinking through certain parallels with our own planning and action – in the energy sector, say, or in transport, or in competitive behaviour. Perhaps we should ourselves

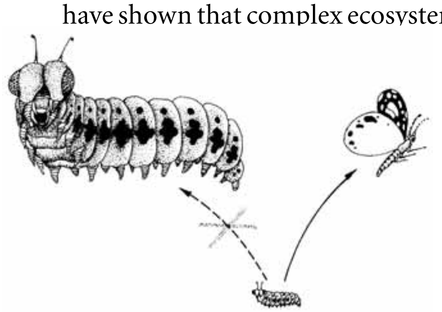
Rule 2

The functioning of the system must be independent of quantitative growth.

The throughput of energy and matter in viable systems is constant over the long term. This minimises the influence of irreversibilities and uncontrolled exceeding of limits.

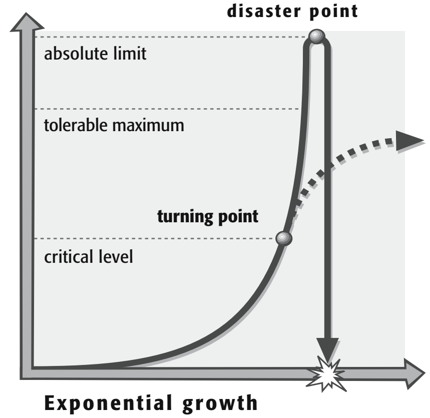
consciously build up one or another protective regulatory cycle.

If a system is to grow and at the same time survive, it must undergo metamorphoses. A caterpillar would no longer be viable beyond a certain size. Moreover, as a caterpillar, however large, the species would be able neither to fulfil its function nor to reproduce. So at just the right time it switches to nil growth, becomes innovative, pupates, and becomes a butterfly – exemplifying how growth alone can never take the place of metamorphosis and restructuring. Analogously, the same is true of all complex systems.
As we have already seen from our discussion of the growth paradigm, the degree of interconnectedness is of crucial importance as regards the stability of a system and its ability to survive. Empirical studies have shown that complex ecosystems are more stable than simple ones.



On the other hand, where you have further uninterrupted growth and a greater and greater degree of interconnectedness, already leading to chaos (when everything is linked to everything else), stability diminishes. This is why in living systems you usually get not a

chaotic network but a superordinate structure that, while within small areas it allows interconnectedness to increase, comprises only a few select connections between those areas and is there characterised by clear 'minimum inter-area effect-flows' (see figs. 8a-c). The most convincing instance of the incompatibility of permanent growth with qualitative structuring and function is our own brain, whose 'hardware' (neurones and their wiring) is already fully grown within a few months of birth. Because here, where maximum function fulfilment in the form of storing and processing information is required, growth would only get in the way; it would interrupt the development of our biocomputer by repeatedly building in new chips and always making it start again from scratch. Which is why its control function (thinking) cannot begin until it has finished growing.



In accordance with the logistical growth curve (see fig. 16), the second rule is not against growth as such but warns against coming to depend on it. Because we then remove self-regulation and with it the principle of the first basic rule, which would normally (that is to say, before reaching the critical inflexion point) lead us via the logistical exponential growth curve into a new stationary phase. With unchecked growth we are simply shifting this process to a higher level of feedback where the repercussions impinge only later but are all the more violent for the delay. A far harsher regulatory mechanism enters into effect, one that leads not to metamorphosis but to disaster. The usually unavoidable consequences in such cases are a greater and greater expenditure of energy and capital followed eventually by collapse. Examples of this can be seen in the business press every day.

Rule 3

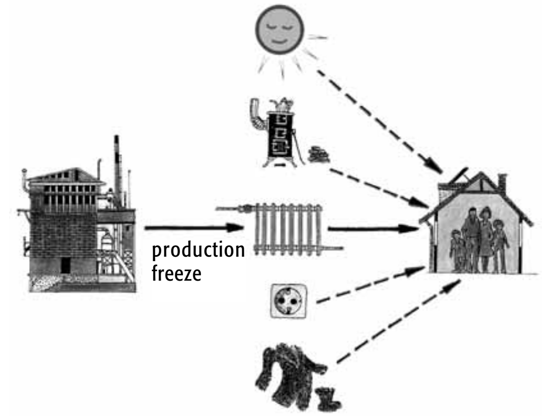
The system must operate in a function-oriented, not a product-oriented manner.

A corresponding interchangeability of supply increases flexibility and adjustment. The system survives even when demand changes.

Systems capable of surviving are geared to their function, not to their product. Only this will give the necessary flexibility, be it to a company or to a regional economic area in times of technological and social upheaval and a constantly changing environment. The fact is, products often change rapidly, whereas functions remain the same for a long time. It is always the meeting of a need and hence the function that is profitable in the long term, not the product, where one-dimensional decision-making makes it very easy to produce without regard to the market. The upshot of our systemic examination for Ford Germany was that the function of a company in this branch of industry should not end with the manufacturer of motorcars but is actually the whole transport business. This is basically a far more interesting field, covering not only the development of a very wide variety of motor vehicles and new forms of transportation but also disposal and supply arrangements (waste-disposal systems, energy boxes) and even improved urban planning and designing a residential structure that may possibly give rise to less traffic. We can now see at least the beginnings of such a re-orientation in connection with certain automobile manufacturers.

Particularly this third rule throws into clear relief the limits of drawing up a purely environmental balance sheet. We have already, with our EMAS recommendations and ISO standards, as with the German DIN catalogue that preceded them, created an extensive web of regulations. However, their weakness (particularly as regards ISO 9000) lies in their product-orientation. This assessment criterion is aimed primarily at existing products and at optimising their manufacture, distribution, transport, sale, and disposal. It is not aimed at the function that the product fulfils or at satisfying the need that lies behind it. In fact, the product as such is never questioned. The generally prevalent fixation on 'the product' means that even the major corporate consultants

often talk only in terms of how the particular product or service concerned can be rationalised, enabling it to be produced more cheaply, penetrate new markets, and be protected against the competition in order that, in an increasingly globalised world, it may continue to enjoy success. Hardly anyone looks into whether perhaps the wrong product is being manufactured or the company concerned has long been producing without regard to the market or offering it poor services of the wrong kind. As is well-known, VW made what for the time was a huge breakthrough onto the world market with its 'beetle' not primarily because of the product but because of the unique service cover the company had achieved. Rationalisation and locational advantage are futile if no one dares to question the product itself. When a product has failed on the market, subsidies are often the last means of salvation. But all they do is cement the situation, whereas the question one should be asking is: what else could we do with this workforce and its expertise that would bring us more market success than we have had up to now? That might be the moment when the possibly long overdue metamorphosis of the company occurs and growth gives way to evolution.



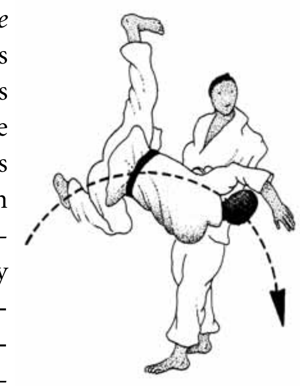
Staying with the example of the car industry, given the workforce's comprehensive know-how in constructing engines and generators, other fields of activity such as aerodynamics and power transformation, warehousing, rolling, springs, pumps, catalytic converters, recycling plastics and metals, manufacturing power-heating boxes for integrated domestic energy solutions, or control technology and electronics might be more appropriate for them than simply building faster and faster touring cars, which basically represent a retrograde step in evolutionary terms, leading up a blind alley.

Rule 4

Exploiting existing forces in accordance with the ju-jitsu principle rather than fighting against them with the boxing method.

External energy is used (energy cascades, energy chains), while internal energy serves mainly as control energy. Using existing forces benefits from current situations and promotes self-regulation.

We all know how such Asian sports as judo or aikido harness clever leverage techniques to get away with using very small amounts of control energy in comparison with the energy expenditure of combat sports. Natural systems generally operate in accordance with the Asian self-defence principle by exploiting already existing (even ostensibly impeding) forces and diverting them in the desired direction with small amounts of control energy – rather than (as is the way with boxing) first combating them with equally powerful countervailing forces and then using a second injection of energy to attain one's true purpose. The principle of prophylaxis instead of repair after the event aims in the same direction: retaining and using the self-cleaning power of wastewater before it is too late, rather than building expensive treatment plants, using riverside forests and the absorbent function of as yet unsealed soils instead of straightening rivers and channelling streams.
Moreover, like solar and wind energy we can also, with the aid of a simple Stirling engine, use every temperature gradient and every bit of waste heat to generate power rather than battling against such things with air-conditioning units that themselves consume energy. According to the same ju-jitsu principle, not only heat-exchangers but also small 15 kW energy boxes such as any car plant can turn out or small combined heat and power generating stations for district-heating pockets are able to make far better use of combined heat and power generation from already-existing energy-sources than a major power station. That the ju-jitsu principle also reduces operating expenditure in other areas and therefore happens to offer effective motivation for protecting the environment is shown by the many instances where anti-pollution measures cut costs and boost profits.



To take two examples, in their 1987 book *The green capitalists* [translated in German in 1989 as *Umweltkrise als Chance,* 'Environmental crisis as opportunity'], Elkington and Burke cited some new and intelligent products and above all Thomas Dyllik used his 'Ecological learning processes in companies' [*Ökologische Lernprozesse in Unternehmungen*, 1990] to show that by taking a radically ecological turn industry could become more efficient and more competitive. The German employers' association B.A.U.M. ['*Bundesdeutscher Arbeitkreis for umweltbewusstes Management' or 'German study group for environmentally aware management*'] also deliberately propagated the multitude of possibilities that already existed in this area, aggressive use of which was to usher in the period of business ecology proper. Because nature, too, with its energy combinations, energy chains, and energy cascades, with photosynthesis and catalysis, has achieved an enviable degree of efficiency, one greater than our engineers would dare to dream of, by using rather than destroying existing structures and materials.

Rule 5

Multiple use of products, functions, and organisational structures.

Multiple use reduces throughput, enhances interconnectedness, and cuts expenditure of energy, materials, and information.

Viable systems favour products and processes that kill several birds with one stone, as it were – which is basically another aspect of the ju-jitsu principle. As little as possible of what we make or do and ideally no single product or process should be used in isolation but rather in conjunction with others, forming a multifunctional system. This of course requires interdisciplinary thinking, all the way from research, through development, to end product. An example of multiple use from one of our transport studies should make this clear. The sketch shows a domestic technology unit for heating, power, and vehicle fuel using a stationary

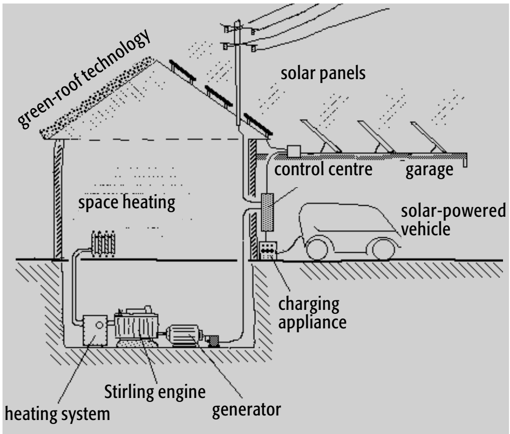


fig. 39: **Running a car in connection with new domestic technology** (from: F. Vester, *Crashtest Mobilität*)

Stirling engine in combination with biogas, a green roof, solar energy, or wind generators. The fact is, one wonders why a city car, which only needs to cover a certain radius, has to have an engine and gearbox at all – why it has to drag its own power station round with it, so to speak, making the vehicle heavy and therefore inefficient in terms of energy economy. The cybernetic solution would be: put the engine in the cellar, harness your waste heat, and use the power generated to charge batteries at the same time.

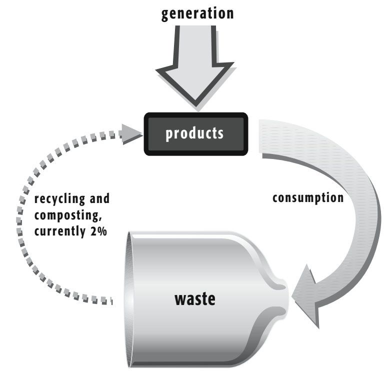
A decentralised and hence more efficient energy supply is thoroughly suited to urban living too: a combined heating and power plant working in conjunction with energy boxes, biogas consumption, insulation materials and fuels made from natural fibres, active and passive use of solar energy, green roofs, wind pumps, energy façades, heat recovery, and so on. In places where the first combination technologies of this kind are already in operation (Saarbrücken, Heidenheim, Freiburg, Erlangen, and Rottweil, to name but a few German pioneers) they enjoy unqualified popularity with inhabitants and have also pulled municipal suppliers swiftly out of the red.

Rule 6

Recycling: Using circular processes to keep refuse and sewage 'in the loop'.

Merge initial and end products together. Materials flow round and round. Irreversibilities and dependencies are both decreased.

The recycling principle offers particularly interesting areas of application for small and medium-sized companies and the craft trades. We



need constantly to remind ourselves that the world of nature knows no such thing as 'waste'. For a very good reason it has developed down the ages a closed materials cycle. Because of the way waste products are usefully reincorporating in the life cycle of the systems involved (each product has its enzyme ready to break it down), basically no distinction can be drawn between an initial product and an end product.

We on the other hand are very aware of the distinction (for the moment, at least), having decided to assign disproportionate value to production as opposed to the transformation of waste. Our fascination with producing things blinds us to the fact that the story has a sequel: production has left us with a more and more threatening mountain of rubbish. To understand the recycling principle, we need to get away from one-dimensional thinking (with its perpetual beginning and end) and instead start thinking in terms of cybernetic circular processes. However, we must be careful not to restrict ourselves to our own little sector but look further afield, seeing it in conjunction with others. Because realising profitable recycling opportunities within a single industry, even within a sector, is much rarer than between sectors of different kinds, where the diversity encountered often leads to some surprising possibilities of exchange. This brings us to the next basic rule.

Rule 7

Symbiosis. Reciprocal use of differences in kind through link-ups and exchange.

Symbiosis favours small-scale processes and short journeys. It reduces energy use, throughput, and external dependence, enhancing internal dependence instead.

Symbiosis is what we call the close coexistence of different species for mutual benefit. Symbiosis not some sort of exotic, out-of-the-ordinary

fig. 40: Ant 'milking' aphids. A typical instance of symbiosis in nature

phenomenon but the foundation of all living systems, and as such it has many manifestations. In fact, it forms the basis of our own lives. It begins at the level of the respiratory particles, what we call the mitochondria inside our cells. Relics of very primitive bacteria, these are supplied with food by the cell and in return manage its energy economy (which incidentally was the precondition for the development of the metazoan or multicellular organism). From there the principle extends to gut bacteria, which live off our food and in return build up vitamins essential to our lives, to lichens, which are a symbiosis of fungi and algae, to certain well-known animal symbioses (among ants, for instance, which milk aphids and in return offer them protection), up to the global symbiosis between the animal and plant kingdoms – that is to say, between photosynthesis and respiration. Symbioses are usually very interesting solutions from the technological standpoint, and we should always be on the lookout for them ourselves because they replace 'short-sighted exploitation' by 'stable cooperation'. Once again, Darwin's 'survival of the fittest' needs further refinement. Because how could symbiosis arise in the first place if, according to Darwin, each living being seeks to create advantages for itself at the expense of others? The 'evolution of cooperation' is indeed an interesting systemic question that Robert Axelrod explored by showing how two parties may benefit from mutual harmonisation or submission, but if one tries to prevail at the other's expense both will simply lose out.

The ecological and economic advantage of symbiosis is that, in leading to substantial savings of raw materials, energy, and transport for all concerned, it takes pressure off the environment. But symbiosis calls for a certain smallness of scale and decentralised structures; it needs a certain blending of functions if it is to come about. In other words, it calls for variety within a limited space. That is why monostructures can never benefit from this principle; requiring far greater expenditure for transport and waste disposal as well as for supervision and control, they

will always (ultimately) cost more and always be vulnerable.

The reason for that is obvious: units identical in kind, stuck side by side within a monostructure, can interchange nothing. They all need the same resources, and they all have the same output. So the demand must come from far away and the waste be transported far away. Reciprocal benefits (what symbiosis is all about) do not exist, which is why, despite every apparent gain in rationalisation, the system is more dependent and therefore less stable.

Rule 8

Biological design of products, processes, and forms of organisation through feedback planning.

Biological design takes account of endogenous and exogenous rhythms, uses resonance and functional fitting, harmonises system dynamics, and facilitates organic integration of fresh elements in accordance with the eight basic rules.

These eight rules mean that every product, every function, and every form of organisation that is to contribute to the survival of our species rather than undermining and destroying it must be compatible with the biology of humanity and of nature; they must conform to the structure of viable systems. This is not only an ecological necessity but increasingly also a psychological and (via the acceptance of goods and services) economic necessity. It extends, for example, to the design of the houses we live in, which rarely evoke any echo within our own being any more. Modern domestic architecture is the brainchild of a generation of architects no longer in touch with the real world. Such architects are concerned only with fulfilling themselves; they are not worried about the people who need to feel at home in their buildings. In other fields, too, non-biological design ultimately fails to address the relevant demand and as such is produced without regard to the market. Yet countless planning disasters continue to result from decision-making processes that ignore this rule.

To take another example, the way the global data network is expanding corresponds to no biological design. The true potential of present-

fig. 41: Irregularity within regularity – a basic principle of biological design: more familiar and more agreeable than geometric uniformity

day forms of electronic communication lies not in the kind of cancerous growth of increasingly networked information systems foreshadowed by the World-Wide Web. On the contrary, it is precisely through unstructured interconnection that dangers develop. My immediate response, as a biologist, is to draw a comparison with nature, where a direct tie-up between different organisms never in fact takes place. Neither circulatory nor nervous systems are ever interconnected beyond the individual organism, and there is a good reason for that: faults and breakdowns occurring in one place should not, if possible, automatically be transmitted to all others. So it is not for nothing that nature renounces an Internet-like infrastructure. The mounting threat of computer viruses spreading via Internet and e-mail, whereby programs find their way into the kernel of the infected computer and as it were uncouple the memory structure of its operating software, is already revealing the dangers of ubiquitous, unlimited interconnectedness.
To comply with biological design, the planning and shaping of our projects must never take place in isolation but always in relation to (a relationship permitting feedback from) the local living environment. If only because of the greater efficiency of the latter, such an approach is more likely to produce viable systems than a remote process of constructivist planning.

General validity of the eight basic rules

In future, therefore, we should avoid not only products and processes but also forms of organisation that violate the eight basic rules of viable systems. Because these are rules that hold good in principle for all living systems from the tiniest cell to the regional habitat. The reason for this general validity is that all the complex systems in our world are so interconnected as to form parts of the same higher order; they all possess a basic pattern that is repeated over and over again through every order of magnitude. This is something we were aware of even before fractal theory came along.
Yet this is the very thing that in fact makes complex systems simple to deal with. Rather than having to identify the individual laws governing each element of a system in order to guide and regulate that element separately, we can apply the eight basic rules for the system as a whole; they are all we need to steer it correctly. In other words, the eight rules can also be seen as the eight capacities enabling viable systems to organise themselves. They are valid universally, not just for the ecosphere but also for the technosphere and hence for all systems created by human beings – companies, municipalities, transport systems, energy systems, political systems, education systems, and so on. Non-observance of them may be all right for a long time to come but will necessitate a greater or lesser degree of extra expenditure on supply, waste disposal, protection, and control, depending on where on the scale between the technocratic and cybernetic approaches one's planning and action are located. However, with biocybernetics pointing the way, each plan contemplated will attain a multifunctional correspondence with the laws of the system and consequently a particularly marked tendency towards stabilisation and hence sustainability.
So nature itself can set us on the right road towards swiftly achieving new solutions, showing us they way to save energy and raw materials and at the same time take the pressure off our environment and our economy. Cooperating with nature (rather than working against it) will always pay for itself in the long run and even help to cut costs. For this reason the eight basic rules are now firm components of the kind of biocybernetic controlling set out by Elmar Mayer, founder of the journal *Controlling Berater* [Controlling adviser], as a supplement to environmentally-aware management. Practised as an environmental audit or better still a systems audit, biocybernetic controlling should go beyond the percentage-of-targets-achieved type of assessment to become an integral element of every forward-looking management strategy. A whole series of companies and institutions have now deliberately and successfully built the eight rules into their corporate policy, treating them as a checklist for an initial (and of course still unrefined) 'systemic compatibility examination'.

10 • From classification universe to relational universe

In his article entitled 'Meta-organisation of information', cyberneticist Magoroh Maruyama very vividly describes three possibilities of perceiving the universe around us:

- --as classification universe
- --as relational universe
- --as relevance universe

In line with these three ways of seeing reality, the information belonging to each would be described as:

- --classification information
- --relational information
- --relevance information.

The *classification universe* is that of our Western tradition. It comprises material, spiritual, and other content classifiable in categories that are mutually exclusive. Its structure is hierarchical and characterised by sub-divisions. Relationships within it are static. The corresponding information is based on all objects, situations, connections, and structures also being divided into categories. Items within a category are comparable, sometimes even indistinguishable. Items in different categories, however, cannot be compared. Classification is objective, with superordinate categories having a more general character and subordinate categories a more specific one. The point of classification information consists in the categories being defined as precisely as possible. All components of the universe are clearly named. Knowledge about this universe is knowledge about 'something'. It is a question of 'what' one studies, what books are written 'about' – not of 'how' or 'why' (that is to say, arising out of what situation).

The relational universe, on the other hand, takes its bearings not from objects but from events. According to Maruyama, when the ancient Chinese saw the will of heaven manifested in particular events, they did not draw a distinction between the will of heaven and heaven itself. In their eyes, there was not first heaven and then the manifestation of its will; the two things were identical. So the question: 'What is the will of heaven?' could never arise in that form. Much the same can be said of the view of reality taken by all cultures (that of the Navajo Indians, for instance) where it is the interdependence of effects that dominates and assignment to a particular order is expressed not through concepts but through relationships and influences.

The *relevance universe* consists according to Maruyama in ideas about how one takes care of the world and appraises it subjectively. Responsibility, concern, and aspiration therefore differ from person to person; they may be egocentric or altruistic, arising out of a wish to impose oneself or a sense of obligation. This view of reality will be organised in the form of evaluations, demands, and strategies. Taking care of something prompts such questions as: 'Am I doing something useful?' 'Is this having an effect?' 'Is it good or bad?' 'Do people believe me when I say I want to help?'. At the level of systemic consideration, these would be questions about the stability of the system, about its viability, about its compatibility with the laws of cybernetics, about evaluating it with the criterion of quality of life or that of the development of strategies of self-regulation.

The answers to these questions belong to relevance information. As Maruyama rightly says, our libraries contain a very meagre store of such information, despite the fact that this (he stresses) is more vital as regards the wellbeing of humanity than the contents of all the world's encylopedias put together. It follows that a large proportion of relevance information comes from the personal sphere, from friends and relations. It comes less from people who are experts in the field in question and more from people who stand in a certain confidential relationship to the person asking the questions.

Brought up though we have been in a tradition of classification-based thinking, not even we 'Westerners' find relational thinking a priori any stranger than, say, the Navajo Indians. We all used to practise it before we went to school. As children, we saw things not as isolated concepts; we saw them in terms of the role they played, their function within the whole. In a series of tests involving pre-school children, to the question 'What is a chair?' we regularly received the answer: a chair is 'If I can sit on it'. And so it went on: What is a house? 'Where I live and where Mummy is.' Summer is 'If it's hot and smells of hay'. As soon as we went to school, that was all over. A chair became a piece of furniture, a house became a building, and summer became a time of year. Things were explained by terms, which were explained by other terms; they ceased to be explained by their connection with dynamic reality.

As a result, the interconnected picture of the world around us, the relational universe of the child, became a classification universe. A subject-specific, linear-causal, often indeed compartmentalised kind of thinking became cemented in us, setting our ideas in a mechanistic world-view that may be accurate in detail but is not at all holistic. More than two centuries ago Friedrich von Schiller took a good look at different ways of seeing and in the process stressed the importance of blurred vision as regards recognising pattern. Writing in 1793, he commented as follows on an essay by Wilhelm von Humboldt about different levels of experience:

> *Surely the same should be true of the progress of human culture as every experience gives us occasion to observe? Here, however, we notice three elements:*
>
> 1. *The object stands right in front of us but blurred and with details running into one another.*
> 2. *We separate and distinguish certain features. What we see is clear but isolated and limited.*
> 3. *We join together what was separate, and once again the whole thing stands before us; now, however, it is no longer blurred but illuminated from all sides.*
>
> *In the first period, there were the Greeks. The second is where we are. So the third is still to be hoped for, and then we shall no longer want the Greeks back, either.*

The last sentence is almost a vision of our current efforts to find a new way of looking at reality such as is appropriate to systems. It bears striking similarities to what Maruyama was describing and what I tried with the aid of the computer image of Abraham Lincoln (fig. 5) to illustrate regarding the different ways of comprehending systems.

An innovation in software development

Our discussion concerning an innovation in electronic data-processing appropriate to systems concerns not only the leap to relational information, to patterns of effect structures; it also concerns the question of a 'library' of relevance information. However, since relevance information is always bound up with a specific situation, a specific place, and a specific time, for such a library this would mean that it requires to be supplemented and updated all the time. This may be why our data banks contain nothing of the kind as yet. Probably a further reason preventing this is that it is equally impossible to store a strategy as complete solution; it is constantly having to be adapted – a requirement that only the possibility of a recursive mode of operation with a permanent opportunity for correction would fulfil, as provided for in our Sensitivity Model.

Although many people have by now developed an awareness of the disadvantages of our fixation on classification and many teachers and trainers try to shift this one-sided emphasis more towards relational information and relevance information, traditional thinking still dominates in almost every sphere of life. It is still the rule that our experience is gathered and measured with the aid of isolated data and divided up into compartments, subject areas, papers, and 'profit centres'. As a result, information entering our brains will almost inevitably land in the classification universe that prevails there. That prevalence is reinforced even in the world of vocational training, where tests are conducted in accordance with the multiple-choice method.

Trying to combat this anachronism with yet more CBT ('computer-based training') seems to me entirely counter-productive. The non-interconnected world-view will only be reinforced by such a procedure. That kind of learning is simply 'taking cognisance'; it demotes understanding reality to a matter of classification and projection – failing to engage key areas of the brain that stand ready to grasp connections, form analogies, and filter out patterns.

If computer-assisted information-processing is to lead to the intellectual skills required in today's situation, this can only happen through an innovation in software development in line with the step-change from constructivist to evolutionary management – as suggested years ago by Ulrich, Malik, Probst, and other colleagues at Switzerland's St. Gallen School of Business [and now 'university'; *Hochschule St. Gallen*]. New kinds of early-warning system based on the same holistic approach have been developed by Peter Gomez (also at St. Gallen), and there is the biocybernetic controlling we have already mentioned, as pioneered by Elmar Mayer.

Theoretically, the difference between constructivist and evolutionary management consists in the fact that, up to now, management theory has placed great stress on the goals of entrepreneurial action, where the rules governing this new type of action (the self-regulation rule, for instance) remain largely unobserved. Within the deterministic paradigm, the idea prevails that, given sufficient effort and smooth-running support from modern technologies and informatics, every detail can be so precisely regulated that the goal will be achieved one hundred per cent. However, since (as everyone knows) this is never the case, each time a target is missed, whether by a long way or only just, the inevitable reaction is further to strengthen deterministic controls. Fredmund Malik has shown that, in practice, a failure of regulation will be countered with yet more regulation, runaway costs meet with even tighter budgeting and cost control, planning errors provoke a further dose of deterministic planning, and so on. Essentially what he is saying is that the requisite qualitative leap is never made, all bets being placed on quantity.

The same applies (and has always applied) in respect of computer development. Criteria such as greater capacity, increased speed, and degree of automation lead to the articulation of highly questionable development goals, while far more important matters such as simplicity, compatibility, reduced vulnerability to breakdown, and user-friendliness are left behind, despite the fact that ignoring them leads to time-losses, crashes, and memory-space problems that no quantitative 'progress' can ever make good.

Our systemic investigations suggest that the kinds of development potential in modern electronic forms of communication that offer real promise for the future lie not at all in a cancerous growth process with increasingly networked information systems operating faster and faster; they are to be found in a qualitative quantum leap in the field of software, the development of which currently lays well behind that of hardware design. I see a sensible way forward, for example, in the development of dynamic data banks capable of selecting key information from the welter of data stored under one or more names. Computers should do the same as our brains: instead of enlarging the information mountain they should help to reduce it, and they should do so by allowing connections to form between individual units. That and that alone would constitute a first step from the classification information of traditional data banks to the relational information of the data banks of the future. Only relational information can answer questions like: 'How are things connected?', 'What will this give rise to?', 'Are there cycles here, build-up processes, critical constellations?' A further step would be the development of software capable of evaluating connections (as regards complying with the biocybernetic basic rules, for instance) and telling the user what is good and what is bad for a system's viability.

Since we are talking about complex systems, the software must also meet appropriate requirements. Wherever the real world is concerned, the data material will inevitably be incomplete, so a degree of fault-tolerance is essential. This is just where relational information will help. With it, many distortions will be caught simply by programming less 'precisely', feeding in not defined points but areas and computing with them. Because when it comes to understanding complex systems it is not even greater accuracy that matters or an even greater density of data but capturing the right connections – much as a gene is 'read' for its relational information during the development of an organism.

All of us who grew up with the categories and criteria of the 'Western' educational system, when we hear a system described (particularly if that system itself describes economic reality), initially feel hesitant about introducing purely qualitative concepts. Qualitative concepts are imprecise and cannot be expressed in numbers; we prefer to rely on 'hard' evidence, on figures, measurements, statistics, 'facts'. However, if all imprecise elements are removed or those that can only be expressed in words (such factors as wellbeing, quality of life, lack of consensus, critical stance, etc.), the picture of the actual system and its decisive influencing variables will necessarily be a distorted one.

The triumph of fuzzy logic

It was predictable that someone, some time, would come up with the idea of devoting a special theory to the non-measurable but no less relevant 'imprecise' portion of reality. It was in the early 1970s that Lotfi Zadeh first developed the theory of fuzzy logic and the use of fuzzy sets (imprecise groups of systemic elements). The terms were introduced to describe the particular kind of imprecision that cannot be measured statistically: lack of clarity, ambiguity, generalisation, and apparent contradiction. All these things, however, are especially typical of environmental systems and social systems.

Long underrated in terms of its scope, fuzzy logic was first embraced by Japanese production technology, where from the programming of robots in car production and process control in the chemical industry to auto-focus in cameras it has contributed to Japan's successes in the field of electronics. Not until much later (the first German fuzzy logic symposium was held in 1991) did it start to gain a toehold here. In an instruction manual about process control written by Herbert Furumoto we read: 'The rules of action can be formalised verbally. Particulars of precisely defined limits are not required. Statements may be imprecise ('fuzzy') and include such terms as 'slightly larger' or 'slightly less'. Even large quantities of technological rules of action can be quickly and easily converted into an automation system.'

As regards practical application, fuzzy logic is now sweeping all before it. To take one concrete example, a fuzzy logic program developed by Herbert Furumoto of the plant technology division of Siemens AG now controls the production processes of a cellulose factory, with the result that these are very much more viable economically and place less stress on the environment. There is an annual saving of 3,000 trees, and the strength of the cellulose is up by 50 per cent. In comparison with traditional 'precise' planning, the same volume of production consumes 14 per cent less energy and there has been a 75 per cent reduction in waste.

In the world of science, on the other hand, fuzzy logic is making little headway. You will not even find it mentioned in further-education and training publications, which probably has to do not least with the negative connotation that our 'exact sciences' place upon the word 'fuzzy'.

What makes fuzzy logic so special, indeed, is the very way it makes use of the imprecise knowledge of real experience, in which conflicting information forms a compromise that then finds implementation. Values remain flexible and also take account of individual parameters. Fuzzy logic thus facilitates the same sorts of flexible control process as those found in natural ecosystems, where it is not precise measurements that matter but rules of action. These can be formulated in words, i.e. in plain language. Not only may statements be imprecise; they may even be connected in imprecise ways. This gives rise to interconnected structures with 'what-if' relations, and what these say is correct because it is an accurate reflection of reality. One of the great advantages here is that this also drastically reduces the amount of data required to describe a system.

Such authors as Hans Werner Gottinger, Joseph A. Goguen, Hans-Jürgen Zimmermann, and (more accessibly so far as the layman is concerned) Bart Kosko have given detailed descriptions of the unique benefits of this approach as an ideal instrument for giving 'imprecise but true' estimates of the interactions of qualitative or strongly aggregated variables.

Back in 1975, when we began developing the Sensitivity Model, it was already clear to me that fuzzy logic (which at the time was scarcely acknowledged) must make the difficult task of capturing complex systems feasible because one can get by with a small amount of data and thus perform mathematical calculations and write programs using concepts of reality that are more or less inexact but are always correctly situated. Certainly, by capturing soft data on the one hand and restricting oneself to a few systemic parameters on the other, one was creating important basic prerequisites for producing a representative picture of even highly complex systems with a few key variables.

To understand that the main thing required here is a changed way of looking at things, we should remind ourselves that our brain is capable of interpreting reality both in a linear-causal manner and in an interconnected manner, depending on whether we are concentrating on details or on the whole picture. To illustrate this we looked at the computer portrait of Abraham Lincoln (fig. 5), with the aid of which we were able to demonstrate the two types of perception. However, for even a crude representation of reality to be correctly reflected using a few components of the system concerned, those components must meet three conditions:

- --They must be correctly selected,
- --how they inter-relate has to be understood, and
- --they must be joined up in a pattern, forming a fuzzy set.

Again, the Lincoln picture (fig. 5) enables us to demonstrate just how much depends on the choice of systemic components and on their position (i.e. how they relate one another) and what importance attaches to their being made fuzzy and our having the right tools for the purpose if the pattern of our system is to be correct. Even the most accurate portrayal of one part of a system in isolation (the mouth region say, on the Lincoln portrait) will give a quite inadequate picture as compared to a portrayal, even a very crude portrayal, of the system as a whole.
We are familiar with this danger in a different context: namely, the sketchy way in which personal details get interpreted. Here is a striking example from an actual data survey of Swiss citizens. Compare the following 'crude patterns' of individual particulars:

Person A	Person B
Chairman of a left-wing soldiers' committee	Lance corporal in the Swiss army Leader of Schaffhausen City Council
Course at Winterthur Technical College broken off after 3 semesters	Opera reviewer
10 previous addresses	Heroes: Rodin and Beethoven
Heroes: Lenin, Trotsky	Member of board of directors of Schauspiel AG (a new company in the theatrical field)
Member of executive committee of Communist Party	

The characteristics of person A suggest a somewhat dubious figure, a bit of a rebel, unstable, not to be relied upon, a possible danger to the state, someone who does not know what he wants and is certainly not creditworthy. Person B, on the other hand, gives the impression of being an established intellectual, the sort of man you would call a solid citizen, someone equipped with useful gifts, responsible and conventional. Well, such conclusions are plain wrong. The fact is, the 'two persons' are one and the same, namely former Swiss MP Walther Bringolf. The particulars are authentic and date in both instances from 1938 (not, that is to say, one set from a stormy youth and the other from mature old age). They were communicated to me by Professor Zehnder of Zürich as an example of the possibilities of manipulation through selective capture of personal data. Random (or deliberately manipulative) selection from data material, even key data, can thus give a false picture. So capturing the character of a system 'crudely yet correctly' using only a few influence variables calls for an additional methodological aid, namely the matrix of criteria described in chapter 11.

Time for another summary:
If we wish to make the leap to a fresh level of organisation where we shall be better able to cope with the complexity of our world, we need more than just a revolution in our way of seeing things; we also need to pass from the classification universe that we have in our heads to a relational universe based on a web of causal links. Otherwise we shall find it hard to practise interconnected thinking. The need for a holistic approach to looking at systems makes two further demands: it requires us to find a way of letting 'soft' data flow into our systemic model (and the long-neglected fuzzy logic theory offers a feasible method here); it also requires a guarantee that, even where the immense number of components involved is represented by only a few variables of the system, the way the system behaves can be interpreted without misrepresentation.
If our plans and actions are to lead to sustainable developments within the meaning of organisational bionics, this imposes a series of requirements on new tools to make it easier (or even possible) to apply the cybernetic, systemic way of looking at things. The structuring of working aids into three levels undertaken in the third part of my book will show how initial interactions already extend our knowledge of a system. Bringing a cybernetic interpretation to bear on it changes the type of prognosis from deterministic forecasts regarding the state of the state of the system to 'what-if' predictions regarding the way the system will behave. A systemically compatible strategy along these lines will then

emerge not from programmes or dogmas but always from the system itself, where the steersman operates as part of the system. Herein lies the basis for a new kind of argumentation with which to beat the shortcomings (visible particularly in the dialogue between economy and politics) of the 'technocratic-constructivist' manner of thinking.

Part 3
The Sensitivity Model

Introduction

Back in the days when I was 'active in science' I was already concerned about the lack of interdisciplinarity and the fractured picture of reality that resulted. I was making my first television films and writing my first books, and they all revolved around this central theme. When I set up my own independent company, Studygroup for biology and enviroment Ltd. [*Studiengruppe für Biologie und Umwelt GmbH*], in 1970 I was able to devote myself entirely to systems research and to propagating systemic thinking. An official paper, the 'Report on the environment' [*Umweltgutachten*], published by the Council of Experts on Environmental Questions [*Rat der Sachverständigen für Umweltfragen*] in 1974, reflected the paucity of interconnected thinking with particular clarity. Important links such as the stress placed on the environment by questions relating to the energy economy or problems having to do with soil and agriculture were simply passed over, and as a result the conclusions of the experts struck me as plain wrong. This prompted me to write a strong article in the German science journal *Bild der Wissenschaft* entitled 'Status quo of the environment problem – no cybernetic thinking' [*Status quo der Umweltproblematik – es fehlt die kybernetische Denkweise*] attacking 'hair-raising ignorance' amongst officialdom and 'certain blinkered sectors of business'. The article made me few friends in established circles, but it did (more than a quarter of a century ago now) impart a decisive thrust to my work. A man on whom my criticism of environmental experts clearly made a deep impression was Alexander von Hesler, then chief planning officer of the Lower-Main regional planning community. Unhappy about current planning methods, he was on the lookout for a fresh approach.

As a member of the German National Committee of UNESCO he commissioned me to produce the bilingual study Urban Systems in Crisis – a guide to understanding and planning human habitats with the aid of

biocybernetics [German title: *Ballungsgebiete in der Krise – eine Anleitung zum Verstehen und Planen menschlicher Lebensräume mithilfe der Biokybernetik*]. This study was the foundation stone of and at the same time inspiration for further development of the Sensitivity Model as 'guide' towards a new way of dealing with complexity. This method, which I presented at the Davos Forum as early as 1980 and which in 1984 was awarded the Philip Morris Research Prize, was constantly improved methodologically in dialogue with a wide variety of users and has eventually, over a 25-year period, evolved into the comprehensive know-how package known as the 'Professor Vester Sensitivity Model', [*Sensitivitätsmodell Prof. Vester*®] with its computer-assisted tools.
Since the German research association Deutsche Forschungsgemeinschaft (DFG) and other comparable organisations refused to sponsor the project, it was eventually the first users themselves who as partners laid the financial foundations for developing the computerised Sensitivity Model. This means primarily the Frankfurt planning firm Frankfurter Aufbau AG (FAAG), the Berlin-based Urban System Consult GmbH, and the Frankfurt Regional Association [*Umlandverband*]; other bodies involved have been the Institute of Insurance at the St. Gallen School of Business with its NERIS study group [*Netzwerk Risiko im Sensitivitätsmodell*], the engineering practice of Drs. Friedl and Rinderer in Graz (Austria), the Nuremberg Consumer Research Company [*Gesellschaft für Konsumforschung or GfK*], and Bayerische Hypotheken- und Wechselbank [the *'Bavarian mortgage and exchange bank'*] in Munich.
Unlike the general 'world models' that had only recently been proposed by various authors, the intention here was to develop what in German we call an Instrumentarium that would help to solve concrete, current problems at no matter what level. Clearly, a fundamentally different new way of looking at things was called for here; we needed to get away from linear cause-and-effect theories and adopt the 'biocybernetic approach' instead.
By 'sensitivity' [*Sensitivität*] we mean something more than 'sensibility' [*Sensibilität*]. We are talking about the tiniest ways in which a complex system responds to internal and external influences. A Sensitivity Model not only reflects the dynamics that determine how a system develops, as 'systems dynamics' models do; it also performs as the recording seismograph and as such is able to describe the cybernetics that prevail within those dynamics. By rendering cause-and-effect flows visible, the method enables the person using it to influence those flows by setting new courses, to improve the constellation of the system by self-regulation, and with the aid of simulations to examine how the system behaves as a result – including the repercussions that simply being aware of those possibilities of influence has on the way it develops.
In the following chapters we are going to try to connect traditional ideas about tackling complexity with the appropriate tools. They grow out of the nature of the tasks to be done, as set out in Part 2, and they show how the requirements of planning practice that relate to systems can be met with an interconnected approach. Extrapolating from what has been learned with the computer-assisted tools of the Sensitivity Model (what we call 'system tools'), we have the *Instrumentarium* we need for a new method of decision-making, the individual stages of which will be explained with the aid of a wide variety of practical examples.

11 • Working tools for an interconnected approach

Since all planning intentions ultimately have to do with a desire to alter existing systems with the aim (often missed, unfortunately) of improving their viability, the manner in which this needs to be done might also be seen in terms of diagnosis of a 'patient' and the course of treatment based thereon. The following diagram (fig. 42) portrays this as a kind of circular process:

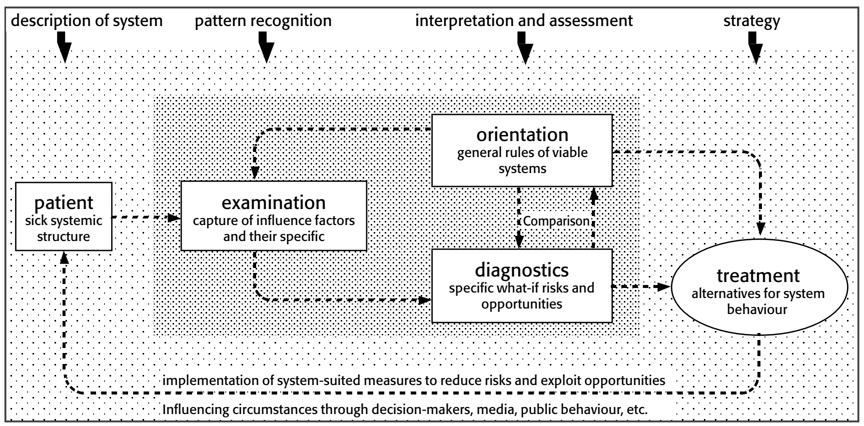


fig. 42: **Simplified view of diagnosis and treatment**

nevertheless systemically relevant set of actuating variables. Special methods of data-screening serve to aggregate these actuating variables and the ways in which they interact. This allows work to proceed with a small number of representative key factors. A special feature of the systemic model is that, with its recursive structure, each stage (including the description of the 'patient') remains open until the end, with the result that the entire model is permanently capable of being updated.

At the second level of the method, corresponding to 'pattern recognition', the interactions present in the system concerned are examined and the system's interconnectedness visualised graphically. Recognising the different roles of the actuating variables within the system and characterising the system's behaviour are essential steps at this level. The tools of interpretation and simulation used for this differ radically (in the interactive way in which they emerge and in their fuzzy logic) from the more rigid approaches adopted by system dynamics. Unlike with ordinary economic cybernetics, here the 'steersman' is not outside the system (taken to its logical conclusion, that would lead to dirigisme) but removes the 'target values' from the system itself by acknowledging the system's own steering potential as well as its latent risks and opportunities.

The third level of the method is the one at which biocybernetic appraisal takes place: assessing the system analysed with a view to making it as viable as possible in terms of (among other things) self-regulation, flexibility, and controllability. The holistic approach and the application of fuzzy logic give rise to an implicit rough guide by which the system (i.e. the 'patient') can be captured and interpreted in a 'diagnosis' model. Subsequent comparison with the functioning of a 'healthy' organism on the basis of the eight ground rules will reveal the appropriate solution strategies from within the systemic context. In the diagram (fig. 42), this phase of the process corresponds to 'therapy', which through a variety of interventions such as particular actions, techniques, resolutions, or political decisions is able to react on the system. The therapy selected can in turn be examined in the model (by means of a simulation, for instance) as to its suitability.

When we approach complex systems in this way, in the diagnosis-therapy schema illustrated in fig. 42 biocybernetic assessment plays the role (in a sense) of permanent orientation model without our never being able to find the right therapy for our 'patient', the system, because we do not in this case have access, as in medicine, to the 'healthy person' as model for comparison.

The structure of a cybernetic system model based on these three levels can be broken down into nine interacting operations:

- ➲--describing the system
- ➲--registering actuating variables
- ➲--checking for systemic relevance
- ➲--studying interactions
- ➲--determining role within the system
- ➲--examining overall interconnectedness
- ➲--cybernetics of individual scenarios
- ➲--'what-if' forecasts and policy tests
- ➲--evaluating the system and formulating strategy

In the following chapters the emphasis will be on describing the tools developed for these operations, using practical examples. But first I want to show, in a brief summary, where and how the requirements of interconnected thinking have contributed towards developing that Instrumentarium (that 'toolkit', let us call it) and the operations it performs. The aim is to comprehend any system, no matter how complex, as a whole in order to be able to develop sustainable treatment plans for it.

➲--Describing the system

In principle it is a question of describing the system concerned in terms of the superordinate goal of 'enhancing viability'. On this basis, subordinate partial goals are defined and the frontiers of the system staked out – a process that will yield a usable 'systemic picture' only through polling and through encouraging the participation of everyone affected by subsequent decisions. This will already obviate several errors in dealing with complexity, errors such as not describing goals adequately, setting points of emphasis too soon, or imposing authoritative behaviour. Documenting this input must remain open and capable of being added to.

➲--Registering actuating variables

From this description of the system, to which researched material, statistics, and the findings of technical and financial reports contribute quite as much as accounts of shortcomings, desires, and opinions, it will now be possible to filter out vital key data and actuating variables that play a role in the way the system behaves. However, these need (as their name implies) to be variable quantities; they must be flexible, not fixed. To 'scan' the system as a whole, these will be ascertained in a brainstorming session with everyone involved and immediately entered in a data bank. In parallel, at an underlying second level of documentation, questions and proposals regarding these variables will be recorded by way of furnishing a more detailed description. Instructions for mediation help to structure the mass of data, find a uniform plane of aggregation, and avoid any doubling-up; they also ensure that not only quantitative but also qualitative data (i.e. the all-important 'soft' data) receive due consideration.

➲--Checking for systemic relevance

Previously we were still at the stage of classification information, and this continues to provide an indispensable basis. Now, however, the process of a selection process appropriate to systems needs to begin if (to fall back yet again on the example of the Lincoln portrait; see fig. 5) we are to recognise all parts of a 'face' from only a few 'squares'. (Note, incidentally, that without the 'squaring' we should never, no matter how much 'fuzziness' we incorporated, be able to find a face here.) What is required is systematically scanning the variables so far assembled from a variety of angles. The system's people and the condition they are in must be taken into account with the same thoroughness as the field of economic or other activities, including use of space (where does what happen) and the way in which the system relates to its environment. Its infrastructure and channels of communication will be examined as much as its 'inner order' – its administration, say, and its laws and contracts. Moreover, a check will be made as to whether the variables captured do indeed represent an actual rather than a theoretical system. The 'three entities' of matter, energy, and information must therefore be represented in the same way as variables that open the system up towards the outside world. All these aspects belong to every system, which is why every collection of variables is filtered with the aid of a 'matrix of criteria'. This gives rise to a set of variables that do not duck any question asked of the system and can at the same time be reduced to a (for the user) manageable quantity of between 20 and 30 components. (How this is achieved and what it looks like in a concrete instance will be shown later, using a practical example.)

--Studying interactions

The first step from classification information to relational information is accomplished by examining the effect of all actuating variables in order to gain a picture of influences and dependencies that may possibly be still 'latent' at the time of the examination. A suitable tool for this is the so-called 'paper computer' that I developed in the 1970s in the form of a matrix of influences – what I termed a 'cross-impact matrix'. In this an estimate of influence magnitudes conducted by one of a number of study groups working in parallel is entered by hand. In addition, an estimate is made of the strength of the effect of each individual variable, should it change, on every other.

In this connection, objectivity is not necessarily a condition of the usability of the effect relations entered. Particularly as regards human relationships, subjective information is often of far greater importance than objective. For instance, the fact that A feels B is hostile towards him/her will have more effect on A's conduct towards B than the 'objective' fact that B experiences no such aversion. This kind of relational information is subsequently gathered fully in effect structures and at the simulation level in that for such processes of perception and interpretation additional auxiliary variables are introduced on top of the 'objective' variables.

--Determining role within the system

From this kind of 'matrix of influence' the position of each variable in the system between the four cornerstone values of 'active', 'passive', 'critical', and 'buffering' can quickly be located. From their different roles in the system, thus identified, it is possible to gauge where the system has its critical points, which factors lend themselves to use as levers, and which factors tend to be sensors and are best left alone. What this shows is, not only individual actuating variables but also entire systems may, for example, be very active or very sluggish. The insights bestowed in this manner not only furnish initial strategic indications; they also, retrospectively, correct both description of the system and selection and definition of variables.

A special feature of the structure of the Sensitivity Model, which even lends a certain 'cybernetic' quality to how the process unfolds and which diverges from the usual constructivist approach, is its *recursive* way of going about things. When at a later stage it is a question of constructing an overall network and examining chains of cause and effect, regulatory cycles, growth tendencies, and limits and thresholds, this presupposes having constant access to the underlying data material and previous steps in the operation and, beyond that, as regards the entire systemic model being worked on, constantly having this automatically updated. So for every system to be investigated a dedicated relational data bank is a prerequisite.

On this point, too, my model diverges from academic convention; normally one proceeds to the next stage of an investigation only once the previous stage has been completed. However, precisely this leads to an inhibited approach, takes an unnecessary amount of time, and will perpetuate any mistakes.

The fact is, in the course of characterising a system the discoveries of each further step are also meant to react on the previous one, with the

The matrix of influence **(originally termed paper computer)** has a long history. I first developed it in 1970 as a tool and test bed for ideas associated with interconnected thinking in the context of a pro-environment ideas competition run by the science periodical Bild der Wissenschaft, and the matrix was first published in a book based on the awards given, 'Let our cities live!' [Unsere Städte sollen leben]. As the module 'matrix of influence' it was introduced into the system-capture procedure set out in my 1976 study 'Urban systems in crisis' [Ballungsgebiete in der Krise], and it was eventually developed further to become an essential step in my Sensitivity Model software. The paper computer is now used by many other agencies as an autonomous tool for interconnected thinking – in landscape ecology, for instance, to furnish images of village revival, in a number of projects within UNESCO's 'Man and the Biosphere' programme, in strategic management to provide a holistic early-warning system in connection with assessments of environmental impact in Switzerland [where such assessment is known as Umweltverträglichkeitsprüfung or UVP], in various Swissair planning teams, in countless university seminars, and in the planning departments of a series of companies.

two steps influencing each other and the entire process of capturing and interpreting the system remaining flexible until the end; in the Sensitivity Model the individual steps are deliberately not worked out to perfection straight away. Rather, implementation of the next step automatically corrects the one before. This kind of correction in a number of repeated 'passes' is simpler and swifter to execute and will ensure more stable results than, say, aiming to perfect the initial set of variables through deep, protracted debate. Construction of the model must be programmed in such a way that this interaction between individual stages is not impeded. Only thus will that the dynamics of the model and hence a cybernetic approach be guaranteed. Here the courage to adopt a recursive *modus operandi* is required, as illustrated in fig. 43 for the nine-stage working programme.

--Examining overall interconnectedness

These initial steps towards a sensitivity analysis (the matrix of influence, for instance, with its assessment of the roles played by different variables) already give clear strategic indications and are able, through the way in which variables are selected, to open up a new way of looking at things and thereby to offer a fresh relationship to the system concerned. Nevertheless, this stage is more likely to reflect the 'genetic tendencies' of the system without saying anything about how many of those tendencies emerge or become active under actual conditions and how this finds expression in the way the system behaves.

Only a two-dimensional effect structure will render the real dynamics of the system visible. This must be so easy to construct that the persons involved in the system can do the constructing themselves and the resultant network can always be corrected and updated in debate. This of course calls for suitable computer software (of a kind that will give even non-experts the requisite access) to render what is being done or has been done transparent at all times. The same software can look at the effect structure and also detect the interconnected regulatory cycles, record the consequences of changes for the network, analyse each feedback loop, and issue warnings or make suggestions (when, say, it is a question of exploiting circular processes or marking delays or external influences).

--Cybernetics of individual scenarios

As a result, sub-sections will very quickly crystallise out from a system's effect structure that can then be examined separately in terms of their cybernetics. A corresponding program will ensure that the tie to the system as a whole is not lost in the process. Here too a relational database is essential.

Up to this point we have penetrated deeper and deeper into the level of decision-making; now it is time to try out strategies, conduct policy tests, and analyse feedback-loops. From such partial scenarios one will then pass to simulating the system's behaviour and the consequences of specific interventions. The predictions to which this leads will of course refer not to the occurrence of specific events but to the way in which the system will react. These are 'what-if' prognoses, designed to discern and test the system's tendencies, limits, and reactions to specific interventions. They make it possible to spot a number of other typical planning errors at an early stage and to find ways of avoiding them.

--'What-if' forecasts and policy tests

To keep the Sensitivity Model meaningful, suitable simulations should be constructed jointly with everyone involved, which is why those simulations must remain fully transparent so far as the people are concerned, even where such people are non-mathematicians. Only with such total transparency, expressed in plain language without a lot of mathematical formulae, will an argument based on a simulation be plausible to those involved and justifiable in the eyes of others, in contrast to something said, no matter how illuminatingly, on the basis (say) of concealed, incomprehensible differential equations. Again, therefore, the task was to create a tool that could be used specifically for this purpose, which in turn became possible only on condition that fuzzy logic was applied. Yet even simulation of special scenarios can only indicate trends in systemic behaviour; it cannot provide forecasts as to what events will occur.

--Evaluating the system and formulating strategy

Step by step, a model is thus built up that even in its early stages allows a new relationship to the system under investigation to emerge. Questions arise that had perhaps never been asked before, and one begins to

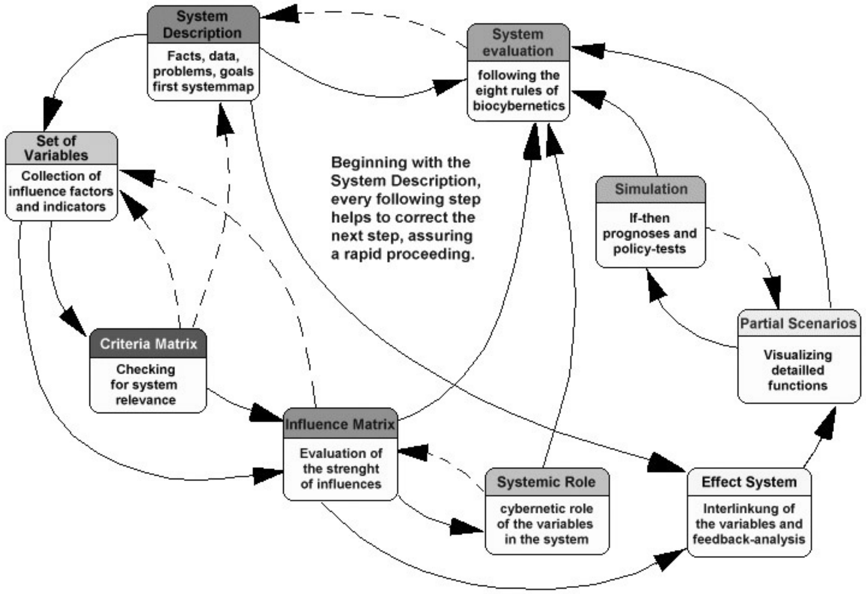


fig. 43: **The recursive structure of the Sensitivity Model**
The above flow diagram offers a glimpse into the recursive, even retrogressive, repeatedly self-correcting way in which the procedure works. Notably, for instance, the definitions and descriptions of the influence factors coming from the set of variables are constantly being supplemented and revised by the findings of the following steps. The same applies to the partial scenarios and their simulation as well as to the involvement of biocybernetic assessment, which re-examines not only the resultant strategy but also the very manner in which the system was originally described.

see initially the particular system and then possibly, little by little, the whole world through new eyes. The matrix of influence itself shows the planner that variables appearing to have the same value may play different roles, which gives those variables a new significance in relation to the system. Analysing feedback loops yields a further strategic indication that may be measured against the checklist of eight basic rules and help to determine the way the questions are put at the next step and how that step is constructed. This consistent openness as regards appraisal and the strategy that emerges are in turn backed up by the recursive modus operandi. Thus the selection of variables will correct the initial description of the system and the way in which it is appraised, processing the matrix of influence will query the definition of many a variable,

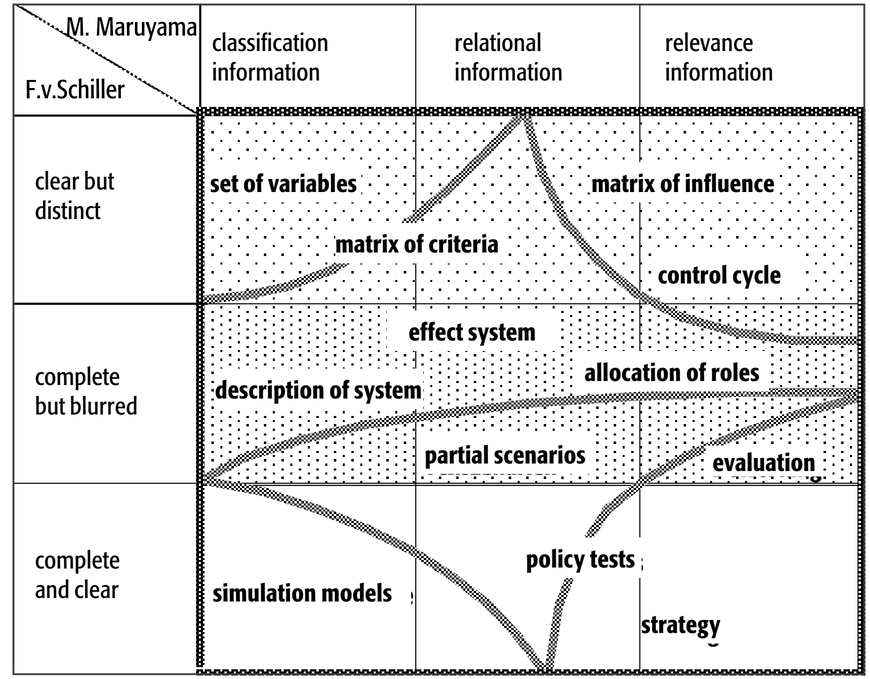


fig. 44: **Arrangement of different instruments of a Sensitivity Model**

and simulating policy tests will uncover further fresh aspects even in the way the system has been described, with the biocybernetic basic rules not merely constituting the first and final authority but being met with at every step along the way. In this way the system under investigation is repeatedly, right up until construction of the model and even during its implementation in a systemically appropriate strategy, checked against itself.

But where inside the multi-layered world of information have we 'fetched up' with this outline of an *Instrumentarium* and its tools, and what dimensions does the 'new way of looking at reality' thus embarked upon in fact open up? Not only the three types of perceived reality discussed by Schiller and Humboldt but also the three areas described by Maruyama (classification, relational, and relevance information) would seem to be covered. To wind up the brief philosophical excursion of the last chapter and apply the criterion of relevance information to the tools of the Sensitivity Model itself, we can relate Maruyama's three types of information to Schiller's three forms of perception and rank the tools discussed in the resultant matrix.

As the graph in fig. 44 shows, the individual steps of the Sensitivity Model extend over all types of conception. The way data is captured ('clear but separate') corresponds mainly to the classifying world-view, though it does contain some relational information. The elaboration of interactions ('full but fuzzy') extends from classification information through relational information (where it uncovers details that, though clear, are unconnected) all the way to questions of relevance. Simulation, while clearly comprehending the whole thing, furnishes mainly classification and only in part relational information. Accordingly, relational information is represented more by the effect system and the matrix of influence. With this kind of arrangement, individual categories do not necessarily rule one another out. Also, the same stage of the operation may come under a number of categories.

Towards an informatics appropriate to systems

In order to have available, for all these steps, a coherent computer-assisted procedure for selective passage through the levels of perception and information described, the only way was to develop one ourselves on a pragmatic basis; no product on the software market matched our requirements here. As indicated in an earlier chapter, I felt it must be the case that, in principle, modern computer technology was quite capable of providing the basis for an approach relevant to systems. However, because of the different nature of the task facing planners in practice, so far as developing a computer program was concerned the most important thing was overcoming those programming weaknesses that had previously spelled failure in most earlier attempts to apply suitable software to capturing and interpreting complex systems.

In Josef Müller and Michael Stolz we found computer scientists who were in fact able to free themselves from all traditional tools and break new ground as regards constructing independent programs (i.e. programs owing nothing to existing writers, graphic aids, and databanks) on a modular basis that so far as possible contain only what is required for the purposes of systemic analysis and that are as reliable as they are user-friendly. In addition to guaranteeing swift access, this process also led to avoidance of the compatibility problems usually encountered.

The aim was a program so constructed as to provide the user with an easy way in to each step of the operation without going through an IT department. Another thing we saw as vitally important was that the computer simulations included in the process should be widely comprehensible; we wanted every user to be able to understand every point. Current simulation programs such as *System Dynamics* and other simpler derivatives such as *Stella* were quite different; they tended to give the impression of an occult science and saddled simulation of interconnected systems with the reputation of being beyond the understanding of the 'average citizen'. And it is a fact that, with these programs, the background 'algorithm' is concealed; it remains incomprehensible to the layperson, and the reasons that lead to the various equations, functions, and curves lack transparency – quite apart from such programs being generally difficult to use. The fear that accompanies any dealings with complexity was not (in contrast to our basic requirement) removed from the person using such programs but rather reinforced. So what was needed, particularly for simulation purposes, was a fresh avenue of approach. A key preliminary here was development of the simulation game 'Ecopolicy' [*Ökolopoly*], which is discussed thoroughly in chapter 20. This gave our computer scientists an initial opportunity to try out the requisite teaching method. The fact that as well as the way in which it proved possible to build purely qualitative factors and linguistic rather than simply arithmetical elements into the mathematical algorithm of a simulation will be shown in detail when we come to talk about the simulation stage in chapter 16.

12 • Describing a system

In this and the following chapters I want to show what concrete implementation of the systemic approach with its new-fangled working aids looks like. The approach outlined in the previous chapter towards a 'sensitivity' analysis will seem unusual to planners and people who have to make decisions. To start with, there is the manner in which the system is described and in which the actuating variables operating therein are collected. In addition we do not follow the usual procedure of drawing first upon existing reports, balance sheets, memos, data sheets, or statistics provided by experts, important though these may be as regards 'feeding' the systemic model subsequently. Instead, capturing the system begins with a brainstorming session involving (if possible) everyone concerned in order that their views, wishes, ideas, and thoughts with regard to the upcoming 'case' may be ascertained and recorded.

In anyone not yet familiar with the methodology of a sensitivity analysis, the initial reaction is one of scepticism. What's this all about? Where are the facts? How can anything of value come out of this? Once the first verbal messages have been recorded on a flip chart where everyone can read them, participants get the feeling that their views are being taken seriously. It helps that the experts and decision-makers present are also required to express themselves in plain terms instead of rattling off incomprehensible columns of figures; their votes carry no more weight than those of everyone else concerned. Since statements of aspiration can always be improved upon, interactively and in full view of all, any inhibitions about speaking 'off the top of one's head' quickly disappear.

After everyone has had an opportunity to make his or her contribution towards describing the system from the subjective point of view and opposing statements and interests have also been noted (which may be a highly turbulent affair but will take between one and two hours at most), the picture that emerges in the course of documenting all the ideas, objections, and suggestions is a surprisingly objective one, around which consensus will automatically prevail. The fact is, no one feels steamrollered or thinks that his/her interests have been passed over or his/her view of things ignored. All the arguments find their way into the data bank and hence into further construction of the systemic model. Differences of opinion remain in play throughout the whole process and do not need constantly to be reiterated anew, and the often endless repetition of standpoints is avoided (some commissions have to mark time for years because they lack the necessary mediation tools).

The process runs in much the same way in connection with every project, regardless of whether the object of concern is the imminent decision about a by-pass around a health resort (for which when it came to constructing a systemic model there were a great many 'volunteers' from the local populace and the city council) or what is on the agenda is the privatisation of a municipal cattle and horse abattoir (for which butchers, restaurateurs, city councillors, and the animal-rights lobby put together an alternative model in a matter of months); or if it is a question of the risk analysis of a small business, or the complex sequence of events that characterises building-site fires, or sustainable development of a particular Chinese region (for which an international team got together with the local authorities and redefined the cybernetics of investment policy). Even in quite other fields, where questions of in-service training, vandalism on public transport, or reform of a hospital are under discussion, the process is always the same.

For example, in connection with an urban-development project in [the German city of] Jena, the very way in which the system was described was able to steer the dialogue in a direction that, according to the city fathers, made possible as never before a genuinely joint approach to a complex subject, with representatives of different sectors (industry, small business, transport companies, regional planning authorities, and nature-conservation bodies) coming together to advise on the future of their city. And when a new type of engineering training was designed at Oensingen Technical College near Solothurn in Switzerland, the Sensitivity Model provided a remarkable stimulus towards a new culture of learning, with each project being approached in an interdisciplinary manner from the outset on the basis of the kind of systemic description we have described. We shall be returning to both examples in the final chapter of this book.

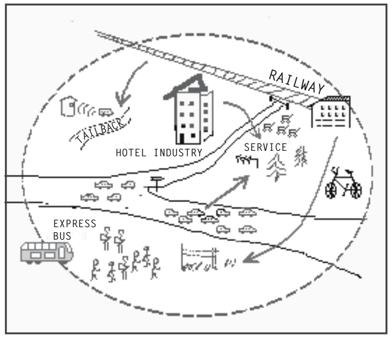


fig. 45: **Traffic-calming system**

Many projects carried out with the aid of the Sensitivity Model show that the course will already be set for the right procedure by the way in which the system is described. This prepares the ground, ensuring that in the ensuing steps of the operation the consensus regarding effect structures, the strength of actuating variables, and latters' role in the system has everyone's support. Accustomed to being presented with a finished model that will provide answers, some people are disappointed at first at having to construct one themselves on the basis of a description of the system. On the other hand, curiosity soon prevails as to how their own input will behave as the model develops. They begin to understand that the model itself, while not actually providing answers, will in a novel way help towards finding them.

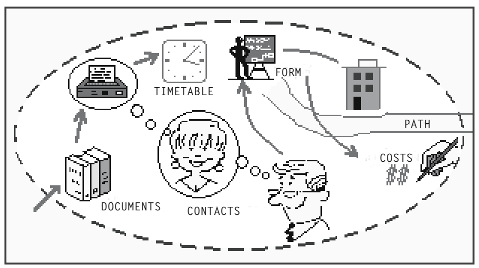


fig. 46: **Further-education system**

So the first understanding of the system aims not so much at a precise definition of the 'problem', more at how the system looks in which the problem at issue is embedded. The *modus operandi* will always begin with the question: 'What sort of system are we dealing with here?' It will seek to address the most important areas of life that must be taken into account in connection with a holistic, interconnected planning process and check those areas in the light of how well or how badly they comply with the eight basic rules. This anticipation of appraisal obviates too swift a focusing on the obvious problems and makes it easier to give a relevant answer to the question of what belongs to the system and what does not.

Rainer Grünig, systems analyst with Winterthur Insurance, drawing on his experience of systemic description in connection with risk analysis as applied to small businesses, writes: 'The purpose of using this procedure is to avoid over-hasty labelling of the problem. Statements

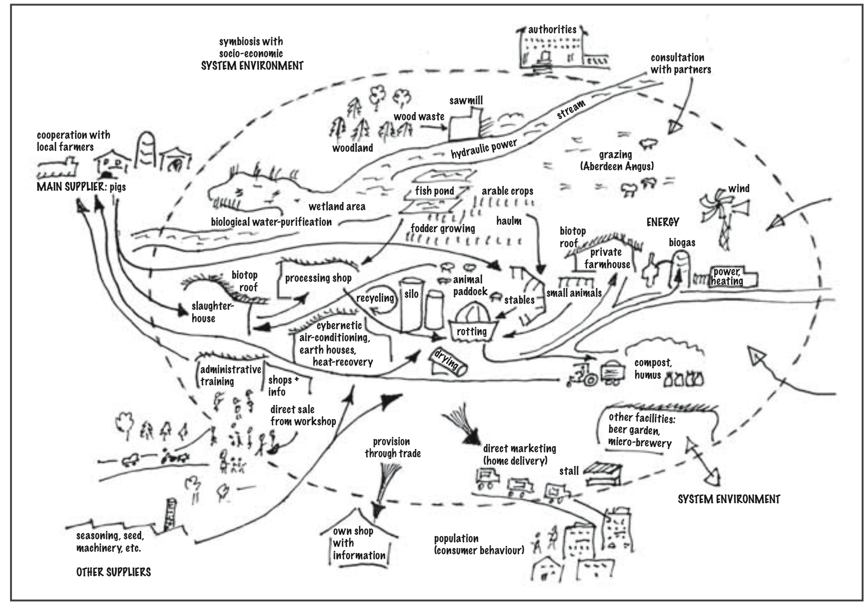


fig. 47: **Rural-workshops system, description of system**

Even discussing such an image of a system promotes interconnected thinking and encourages people to make mental associations along systemic lines. It is a thinking aid that should also serve this purpose in connection with the more familiar methods of 'mind mapping'.

like 'Production holds a hidden ecological risk' or 'The sales chief does not have market risks under control' are very much shaped by a one-dimensional way of looking at things and contribute little to a constructive solution; the fact is, such an analysis of the problem substantially reduces the number of equally valid alternative solutions right from the outset. Rather, one should ascertain the causes of a risk problem as holistically as possible'.

Further description of the system going into more detail and further collection of variables are best done in an interdisciplinary workshop with 'insiders', probing them with the aid of a kind of cross-examination:

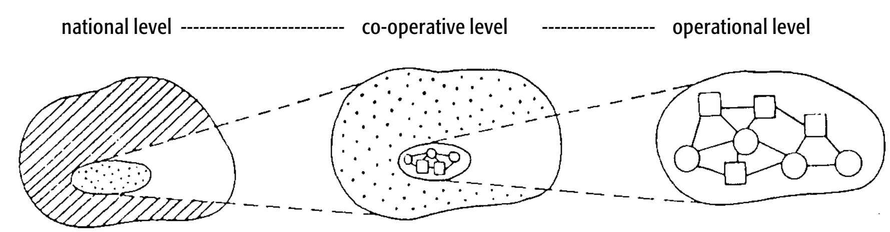
- --Where are the problems?
- --What could be done about them?
- --What is this all to do with?

- --How are limits set?
- --Who is 'anti' and why?
- --What needs preserving?
- --How does the system hold up?
- --What are its special characteristics?

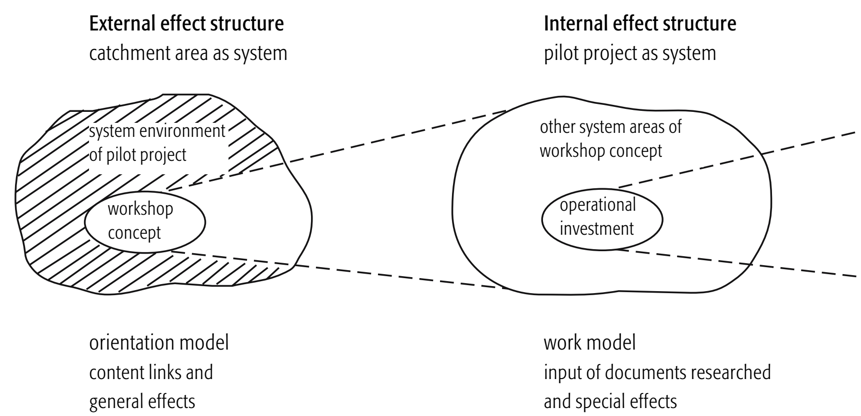
In this way a picture of the system will gradually emerge that can certainly be depicted representationally, regardless whether that system is a business territory, a service company, a training project, or a political conflict situation. Everything can be expressed not only through words but also in pictures or symbols. This will often reveal relationships and connections that would not have occurred to one otherwise. Moreover, this way of going about things trains our imagination and binds our system description to reality in a quite different way right from the start. Very simple system images can already free us from the verbal classification universe. Even a small amount of discussion on the basis of such sketches will help one to think in networks of influence. That is because this approach enables one to see things in context, recognise how they interconnect, and illustrate the links clearly.

Systems within systems

An awkward question is the one that asks how big a system is and where it ends. Since every complex system is itself part of a larger, overarching system and on the other hand is made up of sub-systems, care is needed to ensure that the terms used later for the key variables are on something like the same scale. In other words, to draw once again on our analogy with the computer portrait of Abraham LINCOLN (see fig. 5), the squares into which the picture is divided must have approximately the same dimensions. At this level, classification information comes into its own. One will soon come to see that some terms belong to a very detailed plane while others represent powerfully aggregated collective terms. The former need to be brought together under superordinate terms, the latter may need to be subdivided. The upshot should be that, whatever the system's size, some 100 terms and links are used to describe it. Here is a typical example of 'systems within systems' from the *Ecoland* [*Ökoland*] study, which also formed the basis for Karl Ludwig SCHWEISFURTH's 'Hermannsdorf rural workshops' [*Hermannsdorfer Landwerkstätten, an ecological farm near Munich*] project.



This revision also helps to recognise sub-systems or partial systems, each of which ought possibly to be studied separately as a system model in its own right. On the other hand the presence of a large number of highly aggregated terms indicates that possibly the superordinate system should first be studied using a rough model. For the rural workshops project itself the following subdivision resulted:



The boundary line

Because of this interconnectedness and the resultant overlapping, the boundaries between adjacent systems can of course never be drawn sharply. The most you can have for practical purposes is a boundary line running through the area of 'minimum cross-border flows'; in other words, separating those areas between which the fewest flows of materials, energy, or information take place. To picture this, think back to the three structures of interconnection illustrated in fig. 8; in the last of these (diagram c) we see that the influence streams inside the subsystems are many but that only a few run between them. In precisely the same way, in describing a system one gains an almost vivid sense of the places where incoming and outflowing influence streams are less in evidence. A line can be drawn in the mind through this zone of minimum influence, beyond which the connections possibly become denser again, indicating that they belong to a different or adjacent system.

Complex systems as individual organisms

Generally, though, a more precise demarcation of systems emerges entirely spontaneously in any case as a result of examining the subsequent set of variables with the aid of the matrix of criteria. The fact is, in this phase actuating variables belonging to the system under investigation can be distinguished precisely from externally located incidental conditions or interactions that are without significance. In this way it is possible for the system, together with its immediate environment, to be represented as a separate organism and hence as an individual, distinguishable from other systems.

An open description of the system undertaken in the manner set out here constitutes the first step in the sensitivity analysis, and as such it is particularly important because it lays the foundations for the subsequent recursive, iterative process. We have already stressed how this step will produce useful results only when all concerned have a hand in it and never (as is customary in many consultations) when it is performed by outsiders alone. Unfortunately, many people in business and politics are still quite unable to communicate with and discuss matters with the public in this way. In connection with projects in developing countries, where the donor country's planners are of course always outsiders so far as the local complex system is concerned, a particular risk (this comes out repeatedly in practice) is that controlling interventions will bring about the opposite of what is desired. For this reason it is advisable for the donor country's study group never to draw up the plans for a development project on its own but always, as part of its methodology, to play a merely supportive role based on a systemic approach, offering aid for self-help all the way from the planning phase.

System description in practice

To illustrate this first step of the operation with a practical example, let us look at the planning of a by-pass around the [German] health resort of Bad Aibling. This famous mud-cure town (population: 14,000) in the foothills of the Bavarian Alps had struggled for some time with major traffic problems; in fact, building a by-pass had been under vigorous discussion for 40 years (!).

The project was introduced through a multi-media presentation of the systemic approach at which we set out our idea of an interconnected action plan, which given the complexity of the situation seemed to us to make sense. This event attracted what for a town of 14,000 inhabitants was the remarkable number of 500 citizens. Following discussion of a wide range of views, a group of around 15 persons was appointed. Representing the various tendencies and interest groups, these individuals were prepared to collaborate actively in finding a solution. At a subsequent workshop to survey the arguments, two basic positions crystallised out. On the one hand there was the fear that, because of mounting traffic problems, the patients and holidaymakers who form the economic backbone of the town would one day stay away (with the town becoming an 'emissions spa', people predicted); some therefore saw a by-pass as the quintessential solution. Others took the opposite view; for years, they said, Bad Aibling had itself constituted a kind of by-pass, offering a way of avoiding tailbacks on the Munich-Salzburg motorway. They feared that a proper by-pass might attract even more traffic, placing intolerable stress on future residents in particular while bringing no measurable relief to the town itself. There was no guarantee that, with the by-pass making Bad Aibling a more attractive place to live, internal traffic would not increase accordingly. Better, they said, to block off certain streets within the town itself. This, however, was opposed by retailers, who for their part were afraid of a shopping centre going up somewhere along the new by-pass. Finally, the route of the proposed by-pass traversed a water-catchment area, which brought serious misgivings on the part of nature conservationists into play, and in any case it was not clear, people felt, how the costs would be allocated between state and municipality.

In a nutshell, a typical complex problem; the different actuating variables, facts, opinions, fears and hopes, financial models, and repercussions now lay exposed and needed to be incorporated in a structured system model. A crucial element at this stage was the computer-assisted interrogation of those present, which gave them the opportunity to make sure that not only data concerning traffic incidence, noise and emission measurements, construction costs, sales figures of businesses, and details of access roads were fed into the data bank but also qualitative factors – for instance, words describing the town such as 'charming', 'friendly', 'negative', etc. but also 'fuzzy' terms: 'slightly more', 'fairly large', 'much too loud', 'attractiveness of the landscape', 'protests by residents', 'consent of the town council', and so on. In this way, full use was made from the outset of the advantage of the procedure (namely, bringing both parties, the decision-makers as well as those who would be affected by their decisions, together as interactive parts of an interconnected system).

Description and demarcation of the system and a presentation of the problem that included objective and subjective information and previously disregarded misgivings, desires, and possible solutions – already a new methodological course had been set that, through the ensuing steps of this sensitivity analysis, led rapidly to a solution supported by all.

The press headline ('Compromise after 44-year tug-of-war') that greeted settlement of the problem of the Bad Aibling by-pass is typical of the many cases in which mediation by visualising interconnectedness had smoothed a path from confrontation to coexistence. This is possible only if from the very beginning the chief goal of a systemic study is enhancing the system's viability. That is the only goal that is set in advance; all other goals have to arise from the analysis carried out by the system model. That is exactly what happened here. Since the Bad Aibling project illustrates the process so neatly, I shall cite it again from time to time in ensuing chapters as a methodological example.

13 • The set of variables relevant to the system

In order to arrive at the set of system-relevant variables that is needed for a meaningful, useful cybernetic model, one thing in particular must be accomplished at this stage: our data must be reduced to the essential key components that are systemically pertinent. As we saw from the example of the Lincoln portrait, this is true as regards capturing any complex system, small or large, be it a factory, a company, a municipality, or an ecosystem. Even large systems have a 'face', and here too it is possible in principle to 'recognise' that face. Moreover, it will be recognisable without distortion on one condition: if the otherwise limitless number of components involved is represented by a few key variables.

What are variables?

Variables are quantities that can change; they are a system's nodal points, as it were, the interactions of which reveal, during the course of a sensitivity analysis, the cybernetics of the system. They may express objective facts or values based purely on past experience; they may be either quantitative or qualitative in character. To draw up a set of variables, only the concepts gathered in the description of the system and the system image are used at first. Some can be taken over as they are; some are blanket concepts and must be broken down into a number of variables; others, so long as they belong together in terms of content, will need to be summed up ('aggregated', we say) in a single variable. The object is that the variables on which the unfolding system model is to be based shall if possible belong to the same level of aggregation and represent individual parts of the system as neither too prominent nor too weak, with the result that the foundation of the sensitivity analysis is a manageable set of 20 to 40 variables ascertained in this way. This order of magnitude is by no means arbitrary but arises, as we shall be demonstrating, from the fundamental properties of complex systems.

Not only the group theory of mathematics but also the synergetic studies of Hermann Haken show that it is possible to describe even very complex systems roughly but adequately with the aid of a small number of variables, provided that on the one hand specific system criteria are taken into account and on the other hand the connections between the variables (forming their 'interaction structure') are captured.

Description of variables

The name of each variable is always simply the abbreviation of a system component. So an integral part of each variable is a description of the indicators by means of which it is more closely defined and that one has constantly to bear in mind when working with it if one is not to lose sight of its overall character (which can never emerge precisely from the abbreviation). The indicators are also useful when it comes to representing the variable concerned (possibly from one special point of view) in subsequent partial scenarios. Unlike the main variable, which is usually qualitative, most indicators tend to be far more quantifiable. For instance, 'size of membership of alternative driving clubs' is an indicator for the qualitative main variable 'technological criticism'.
In this way the assembled actuating variables and connections of a material, energy-related, or communicative nature are classified and structured. This happens through breakdown or summary, through checking for similarity of content, and through precise description of evidential value, as a result of which any overlaps become apparent. One or another variable shows itself in the process to be indispensable as regards characterising the system, or it turns out that such characterisation is already contained in the description of other variables. With this second stage of the operation, too, as with description, what one discovers about the system under investigation is considerable, not least as a result of seeing all of a sudden that previously, because of the usually restricted field of view, only a few variables had been taken into account. Even if the model was taken no further, a traffic measure or corporate strategy based on the broad view thus obtained could on this point alone be far better assessed than before.

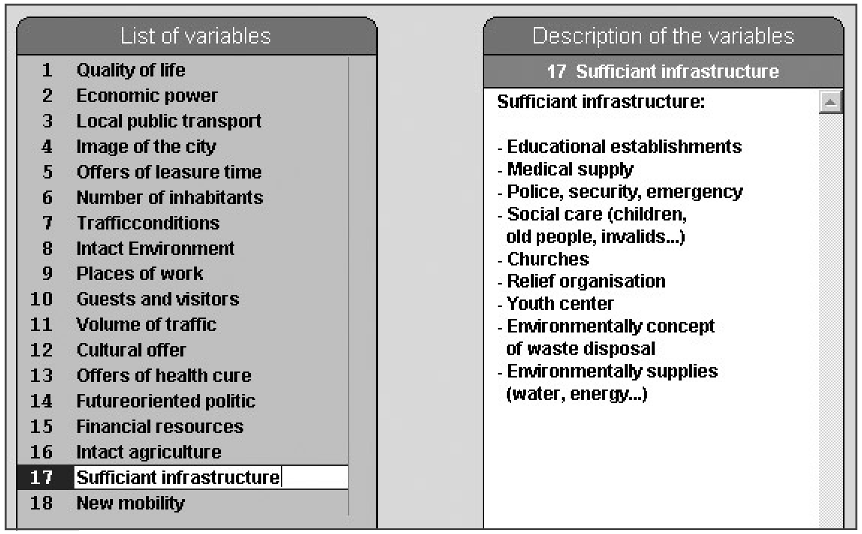


fig. 48: Set of variables with click-on description (Bad Aibling system model)

Qualitative orientation

Certain variables stand out for the fact that a judgment has already entered into their being formulated. However, that 'judgment' in no way influences what the subsequent effect structure or matrix of influence says but simply serves to give the variable a specific direction, which can equally well be reversed. This kind of qualitative orientation is an important prerequisite for working out an effect structure; the fact is, a variable is always something that can vary, something that moves. If we want to understand the effect connections between variables that are of such central importance as regards the cybernetics of the system, we need to be able to describe the direction in which a variable moves (e.g. in response to the influence of another). But to enable one to ask whether a variable is 'decreasing' or 'increasing', that variable must have a qualitative orientation. For instance, the label 'management' is not enough because that is not something that can decrease or increase; it can only be good or bad. So the variable must be called 'management efficiency' or 'forward-looking quality of management'. That can indeed go up or down in consequence of the effect of another variable.

Concerning type of variable

By applying fuzzy logic, every stage of capturing and interpreting a system can be worked through with the same set of variables comprising 'hard' and 'soft' influence factors. Using appropriate table functions, even imprecise, purely qualitative effects can be described mathematically, with the result that the same variables can also be employed in the subsequent simulations. On the other hand, even in connection with such quantitative actuating variables as budget, number of workers, energy consumption, etc, the quantities themselves may not appear in the set of variables (that would make the quantity look like a constant) but only in the description of the variables. In order to remain 'variable' and not complicate the overall picture, quantitative details that may change remain in the background for the time being, constituting a second level of data, as it were.*

Successive construction

In this way material captured flows into a manageable number of qualitative and quantitative key variables with which a convenient cybernetic model can then be constructed. Since this set of variables can be worked with in all subsequent phases, occasional checking of variable definition is advisable in keeping with the recursive *modus operandi* we were talking about earlier. In our experience, the broader the range of views that can be clarified with this definition, the more this applies. One side effect often noticed by users is that in this way the project group finds its way to a common language and gains a more precise idea of what the others are trying to express by the terms they employ.

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* In this connection, here is a typical example from the system study 'Developmental possibilities of a company in the motor industry, given a function-oriented corporate strategy' (FORD system study, 1988 study group of biology and envoironment):
For the variable 'materials and energy throughput' (one of the 22 variables of the 'motor industry' system), the data from the annual output of 4.3 million cars and estates – i.e. the energy consumption of 35 million kilowatt-hours for their manufacture (and about twice as much again for the material used, calculated from the amount of raw materials used, namely 1.2 t per vehicle), the consequent

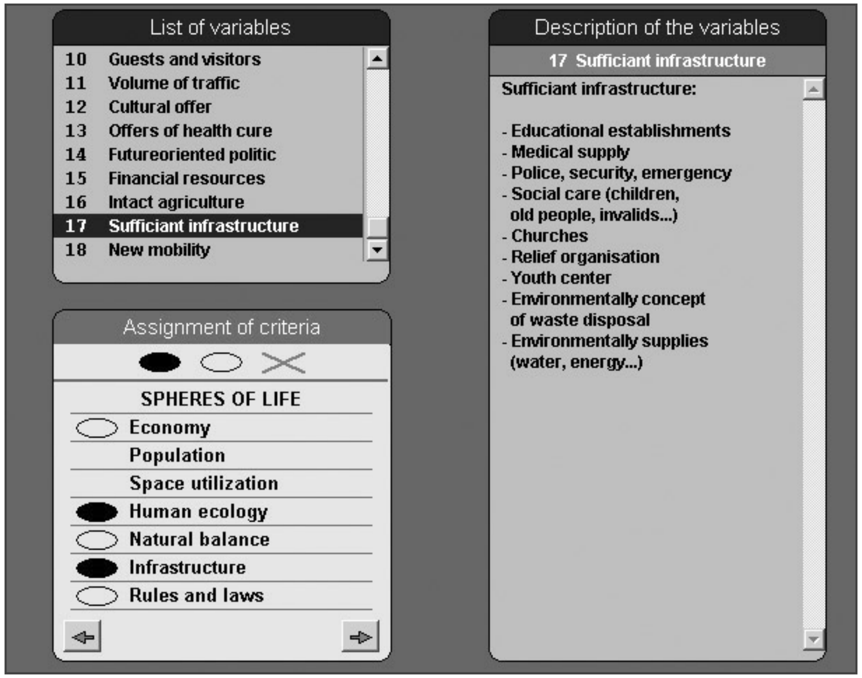


fig. 49: **Entry of system criteria in 'spheres of life' category (Bad Aibling system)**

The choice of 'suitable' variables that emerges from description of the system is governed on the one hand by the actual questions addressed by the project concerned and on the other hand by systemic considerations. As a result, a good combination is guaranteed between those variables that occupy the centre of interest and those that characterise the equally important context. Certainly, a truly system-relevant description depends not so much on the number of variables as on their being put together properly.
The next section shows that the set of variables, if it is to ensure its own systemic relevance, must meet a whole range of criteria that are at the same time capable of reducing it to essentials. Duplications are merged, sub-variables adopted as description, and the set thus brought to approximately the same level of aggregation.

approx. 100 kg of combustible waste, 20 kg of plastic waste, 65 kg of ash and building rubble, 40 kg of sludge, 75 kg of industrial effluent, the approx. 400,000 goods wagons (or 1 million HGVs) required to transport the vehicles, and the 37% of materials costs in the purchase price – form the changeable quantitative 'background', as it were, to the 'materials and energy-consumption' variable. That background can be retrieved and updated at any time and also be distributed among a number of variables in later partial models.

The matrix of criteria

To make a system model convenient to use, it is essential to reduce the variables to a manageable number. However, the only way to obtain a meaningful combination without omitting essential characteristics is by checking the set of variables as to whether it meets the principal system criteria. If this is not done, it is all too easy to fall into a one-sided way of looking at things – emphasising the economic sphere, say, or that of nature, while ignoring the energy aspect, or omitting precisely those factors through which the system remains open towards the outside world. In keeping with the recursive method, therefore, this step will once again alter and add to the old set of variables, diluting one-sided emphases and redefining terms or finding new descriptions of them.
In order to verify in a purposeful manner that the set of variables covers all the fundamental aspects of the system needed for the model to reproduce reality, each individual variable is checked to see which criteria it fulfils and the results are entered in a matrix. The set of variables is revised over and over again until it reflects in a more or less balanced way all aspects and criteria necessary if the model is to reproduce reality. Although these are in fact characteristics that play a role in every viable system, in any normal consideration of variables they do not necessarily stand out. Key components of a system are the areas of life mentioned back in chapter 11, which are covered by seven levels of consideration, plus the three entities of matter, energy, and information, four aspects of system dynamics, and four types of a variable's relation to the system – a total, that is to say, of 18 criteria that should be represented in the set of variables of any system-relevant model.

Definition of the seven areas of life, as exemplified by two different systems

Area of life and fundamental question	System: Regional planning	System: Company
Paticipants Who are they all?	Population, number, structure and dynamics, working people, age structure	Customers, visitors, supervisory board, employees, casuals, shareholders, works committee
Activities What do they do?	Economy, structure, capital, production, tax receipts, debts, shareholder value	Turnover and profit, jobs, services, purchasing / sales, production, investments
Space Where happens where?	Use of space, orography, land development, arable, fallow, residential structure	Distribution and size of workplaces, warehousing, distances
Mood How do people feel?	Human ecology, social structure, quality of life, security, education, state of health	Motivation, identification, competitive struggle, ideas, creativity, sick days
Natural balance How does resources budget work?	Natural economy, consumption of raw materials, energy, and water, soil sealing, influence on climate	Consumption of raw materials, energy, and water, recycling, waste, exhaust gases, acceptability of product
Internal processes What channels of communication are there?	Infrastructure, transport and access roads, telecommunications, traffic and supply	Transport and access roads, communication and information processing
Internal order How is this regulated?	Local government, taxes, measures, ordinances and legislation, planning procedures	Management, hierarchy, type of company, in-house organisation, salaries, corporate culture, agreements

Definition of a variable's physical base criteria

Matter

Variables having a primarily material character
(e.g. buildings, raw materials, means of production, people, animals, plants, vehicles)

Energy

Variables having a primarily energy-related character
(e.g. power consumption, workers, energy carriers, financial strength, decision-making authority)

Information

Variables having a primarily information-related and communications-related character
(e.g. media, decisions, explication, exchange of information, orders, perception, acceptance, attractiveness)

Definition of a variable's dynamic base criteria

Flow size

Variables expressing primarily flows of matter, energy, or information within the system
(e.g. power consumption, traffic, commuters, instructions, attractiveness)

Structure size

Variables serving to determine structure rather than flow
(e.g. green spaces, population densities, traffic network, accessibility, vocational diversity, centralised or decentralised division, hierarchy)

Temporal dynamics

Variables that at the same location change at a given time or that possess a temporal dynamics
(e.g. seasonal activity, election meetings, climatic factors, transport timetables, tax checking)

Spatial dynamics

Variables that at a given time differ from location to location
(e.g. traffic revenue, industrial effluent, nature-conservation area, structural enhancement)

Definition of a variable's system-relatedness

Opens the system by input

Variables that open the system through influences from outside
(e.g. precipitation, dumping, imports, tourism, supra-regional enactments and decisions, subsidies)

Opens the system by output

Variables that open the system through influences from inside the system inquestion
(e.g. waste water, commuters leaving the city, exports, supra regional taxes, image public relations)

Controllable from inside

Variables that can be controlled by decision-making processes coming from within the system under consideration. Among other things these are a measure of the system's self-sufficiency.

Controllable from outside

Variables that are subject to decision-making processes taking place outside the system under consideration. Among other things these are a measure of the system's dependence.

Analysing and evaluating system criteria

So capturing a system requires 18 criteria to be taken into account. If some are missing or even if only one is left out we get a distorted, indeed false picture – as if in the portrait of Lincoln the mouth section or the section depicting the right eye were not there. In the belief that they capture reality, systemic models are often put forward that, for all their extreme detail, in fact reproduce only a few aspects. If, for example, the ecosystem model of a riverside landscape captures precisely and even simulates all animal and plant species, of the seven areas of life it is basically taking account only of the level 'participants' and of the level 'environmental relations'. Yet even if all seven areas of life are included, a false image may still arise. This would be the case, for instance, if an ecological system model took account only of the energy aspect, whereas for system-relevant capture all three ontological entities (that is to say, matter and information as well) are necessary. If the information aspect is not considered, all official decision-making processes will be lacking, for example, and if the matter aspect is neglected the bounds of the area concerned, the food supply, and transport routes will all be left out of account.

To make this clearer, let us look at the opposite case. Regarding the same riverside landscape, a group of landscape planners might develop a completely different but undoubtedly equally detailed system model that focused on the value of the land, leisure activities, use of proceeds to develop a fitness trail, interactions with a neighbouring campsite, and putting a road through. In the first instance as in the second, a one-sided picture would result that said nothing about either the viability of the system or about its development and how it would react to interventions. The two system models would therefore never be able to communicate.

So on the one hand the matrix of criteria helps to add important aspects to the set of variables, but on the other hand it also helps to reduce it. Although the set should cover all the aspects interrogated in the matrix of criteria, it should not include any more variables than are absolutely necessary to describe the system and the problems on the agenda. One side effect is that such checking throws up information not previously

● FULLY applicable
○ PARTIALLY applicable

	Criteria →	SPHERES OF LIFE							PHYS. CATEG.			DYN. CATEGORY				SYSTEM RELATIONS			
		Economy	Population	Space utilization	Human ecology	Natural balance	Infrastructure	Rules and laws	Matter	Energy	Information	Flow quantity	Structural quantity	Temporal dynamics	Spatial dynamics	Opens through input	Opens through outp.	Influenced f. inside	Influenced f. outside
1	Quality of life				●	○	○		○		●		○	○	○		●	●	○
2	Economic power	●	○						○	●	○	○	○	○		●	○	○	○
3	Local public transport			●			●	○	●		○	○	○	○	○	○	○	○	○
4	Image of the city				●						●	●		●			●	○	○
5	Offers of leasure time	○		○			●		○		●		●	○	●		●	●	
6	Number of inhabitants		●						●			○	●	○	○	○	○	○	○
7	Trafficconditions			●			●	○	○		○		●		○	●	○	●	○
8	Intact Environment			●		●	○		●	○		○	○	○	○	○	○	●	○
9	Places of work	●	●		○			○	○	○		○	○	●	○	○	○	●	○
10	Guests and visitors		●						●			●	○	○	○	●		●	●
11	Volume of traffic		○	●	●	●	●		●	○	○	●	●	●	●	●	○	●	●
12	Cultural offer	○		○	●		●				●		●	○	○	○	●	●	
13	Offers of health cure			○	●	○	●				●		●		●		●	●	
14	Futureoriented politic				○			●		○	●	●	○	●		○	○	●	○
15	Financial resources	●						●		●	●	●	○	●		●	○	●	○
16	Intact agriculture	●		●		●	○		●	○	○		●	●			○	●	●
	Sum:	5.5	4.0	7.5	7.5	5.0	9.5	4.5	10.5	5.5	11.0	8.5	13.0	11.0	8.5	9.0	11.0	16.0	9.0

fig. 50: **Matrix of criteria (Bad Aibling system model)**

examined regarding the actuating variables selected; whether, say, a variable is subject to a time dynamic (it might be 'seasonal', for instance), or whether it can be controlled from within the system itself or responds only to outside influence. Ignorance on this count often leads to substantial efforts being undertaken to change a situation that simply cannot be changed internally – a fruitless waste of energy and time that we see frequently in connection with long-drawn-out political decision-making processes.

Size of the set of variables

I have already alluded briefly to the fact that the number of 20-40 key variables required to represent a complex system is not selected at random. If the fundamental properties of such a system are to be taken account of in the set of variables, at the very least all seven areas of life, each with its three entities, must be represented, which would mean $7 \times 3 = 21$ variables. Even if a model has matter, energy, and information flows in all areas, that will say nothing about the structure of the energy flow, say (whether it proceeds outward from a centre in a star shape or is decentralised, being distributed over the whole surface), or about whether the information flow consists of bilateral relations between 'client' and 'server' or is distributed ubiquitously via the Internet.
In these four cases energy flow and information flow may be equally great but in the former instance, in connection with energy, there will be a waste heat problem while in the latter there is not. With regard to matter, too, everything depends on how it is stored (distributed over a wide area or at a small number of centres) or how it is transported (along a few supply lines, from a distribution centre, or through a widely branching network. In brief, the 21 criteria we have so far assembled need to be represented not only in their 'flow' aspects but also in their 'structure' aspects, which would require a set of at least $7 \times 3 \times 2 = 42$ variables. Since allowing for the remaining categories of the matrix of criteria (the system dynamics and system relations aspects) is not compulsory for all areas of life (they can be distributed differently), the number of variables does not increase as a result.
However, one variable will often cover several criteria belonging to the same category. The variable 'motivated staff', for example, covers not only the level of participants ('who are they all?') but also of activities ('what do they do?') and mood ('motivated'). So usually fewer than 42 variables are required. Depending on the 'versatility' of the variables used, the ideal number will be somewhere between 20 and 40, and with some systems it will be under 20. The more 'versatile' a variable is, the more strongly it will also be aggregated. Consistent application of this principle would mean that a very much smaller total of variables is required. However, one would quickly reach a very elevated plane of observation where things said about the system would in fact be too general.
Once the individual variables have been allocated to the system criteria applying to them, in the resultant matrix the distribution of the entries among the 18 system criteria is calculated and it is then shown how these can be represented by the set of variables as a whole. This check

against the matrix of criteria can in turn lead to a redefinition of variables or to deletions from or additions to the set of variables.
In studying a system, therefore, it should always be borne in mind that only a thorough checking of variables against the matrix of variables can make the system represented recognisable as a specific 'individual entity' with a character of its own. That is why a sensitivity analysis of even very similar systems will always be a 'one-off'. It will vary from location to location, coming up with unique strategies and non-identical prescriptions each time. It is precisely this individuality (as reflected in the matrix of criteria also) that guarantees appropriate and feasible solutions enjoying general agreement – as the results from the spectrum of application reproduced in chapter 19 will confirm.

14 • The inherent effects of the system

In the last chapter we looked at variables, their content, and their nature. We are by now thoroughly familiar with the individual components of the system and the criteria they represent. Only at this point can we concentrate on the actual goal of forming the model: namely, analysing its effects in the systemic context.
Since the role of a variable can never be identified from the variable itself (no matter how precisely it is studied, measured, or analysed) but only from the entirety of its interactions with all other components and their own interactions amongst themselves, the first step towards a cybernetic description of its role consists in estimating the way in which that variable influences each of the others. This automatically means allowing what the individual components of a system say to retreat into the background behind the connections between them; it means, in fact, seeing those messages in a new light as a result of examining those connections. That examination occurs with the aid of a simple matrix of influences. In the process, a rough estimate will be reached both of the individual variable's dominance/susceptibility to influence and of the part it plays in events in the overall system. Involving the interactions between the variables brings the previously static set of variables of the system model to life for the first time.
It is an advantage to form three distinct groups for this purpose, each one 'interdisciplinary' in composition. Each of these will independently go through the descriptions of variables before it and examine the effects of those variables on every other variable. Here only direct effects should be noted – effects, in other words, that are not mediated through other variables. In the matrix (see fig. 51), the variables are listed from top to bottom and again in the same order (with

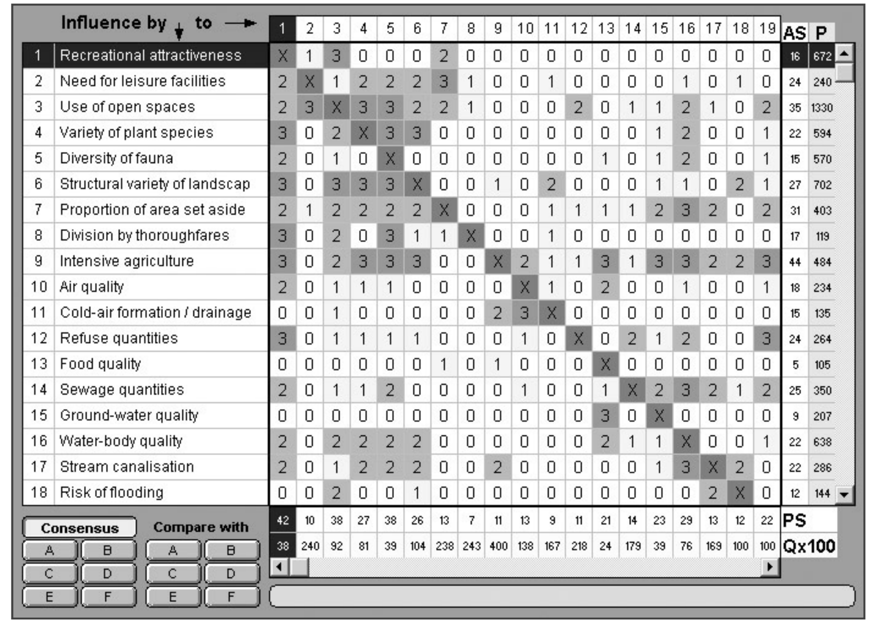
	Influence by ↓ to →	1	2	3	4	5	6	7
1	Recreational attractiveness	X	1	3	0	0	0	2
2	Need for leisure facilities	2	X	1	2	2	2	3
3	Use of open spaces	2	3	X	3	3	2	2
4	Variety of plant species	3	0	2	X	3	3	0
5	Diversity of fauna	2	0	1	0	X	0	0
6	Structural variety of landscap	3	0	3	3	3	X	0
7	Proportion of area set aside	2	1	2	2	2	2	X

fig. 51: **Matrix of influence (excerpt)**

their numbers) from left to right. Since variables cannot directly influence themselves, all the boxes in which a variable encounters itself are marked with a cross.
Strengths of connections are given values between 0 and 3.
The question is always this: if I change element A, how strongly (in whichever direction) does element B change as a result of direct influence by A?

- If I change A only a little and B then changes a lot, a 3 is called for (disproportionally strong connection).
- If I need to change A a lot in order to achieve a more or less equally big change in B, a 2 is entered (medium-strength, more or less proportional connection).
- If a marked change in A brings about only a weak change in B, we award a 1 (weak connection).
- Where there is no effect at all, a very weak effect, or an effect occurring only after a lengthy delay, we put a 0 (no connection).

The number entered is the one on which the group agrees after a certain amount of thought and discussion; the decision may have reasons appended to it. When all boxes have been filled in, depending on whether totals are active or passive the first indications can already be gained.
The 'active' total of a variable and hence an indication of how strongly it affects the rest of the system is obtained by adding up the numbers in a horizontal row. Adding up the numbers in a column, on the other hand, gives the 'passive' total, which indicates how susceptible the variable is to changes in the system and how it will react to them.
The principle can best be explaining using a practical example, in this instance a local recreation project (see fig. 52):
Variable 12, for example ('Litter quantities'), has a relatively high active total (24); in other words, quantities of litter need to change only a little for all sorts of things to happen in the system, which has 26 variables in all. By contrast, if the total is relatively low (like the 5 here for variable 13, 'Food quality'), a lot needs to happen to that variable before anything changes in the system. It is different with passive totals. In our example, variable 3 ('Use of open spaces') has a very high passive total, suggesting



Influence by ↓ to →		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	AS	P
1	Recreational attractiveness	X	1	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	16	672
2	Need for leisure facilities	2	X	1	2	2	2	3	1	0	0	1	0	0	0	0	1	0	1	0	24	240
3	Use of open spaces	2	3	X	3	3	2	2	1	0	0	0	2	0	1	1	2	1	0	2	35	1330
4	Variety of plant species	3	0	2	X	3	3	0	0	0	0	0	0	0	0	1	2	0	0	1	22	594
5	Diversity of fauna	2	0	1	0	X	0	0	0	0	0	0	0	1	0	1	2	0	0	1	15	570
6	Structural variety of landscap	3	0	3	3	3	X	0	0	1	0	2	0	0	0	1	1	0	2	1	27	702
7	Proportion of area set aside	2	1	2	2	2	2	X	0	0	0	1	1	1	1	2	3	2	0	2	31	403
8	Division by thoroughfares	3	0	2	0	3	1	1	X	0	0	1	0	0	0	0	0	0	0	0	17	119
9	Intensive agriculture	3	0	2	3	3	3	0	0	X	2	1	1	3	1	3	3	2	2	3	44	484
10	Air quality	2	0	1	1	1	0	0	0	0	X	1	0	2	0	0	1	0	0	1	18	234
11	Cold-air formation / drainage	0	0	1	0	0	0	0	0	2	3	X	0	0	0	0	0	0	0	0	15	135
12	Refuse quantities	3	0	1	1	1	1	0	0	0	1	0	X	0	2	1	2	0	0	3	24	264
13	Food quality	0	0	0	0	0	0	1	0	1	0	0	0	X	0	0	0	0	0	0	5	105
14	Sewage quantities	2	0	1	1	2	0	0	0	0	1	0	0	1	X	2	3	2	1	2	25	350
15	Ground-water quality	0	0	0	0	0	0	0	0	0	0	0	0	3	0	X	0	0	0	0	9	207
16	Water-body quality	2	0	2	2	2	2	0	0	0	0	0	0	2	1	1	X	0	0	1	22	638
17	Stream canalisation	2	0	1	2	2	2	0	0	2	0	0	0	0	0	1	3	X	2	0	22	286
18	Risk of flooding	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	2	X	0	12	144
		42	10	38	27	38	26	13	7	11	13	9	11	21	14	23	29	13	12	22	PS	
		38	240	92	81	39	104	238	243	400	138	167	218	24	179	39	76	169	100	100	Qx100	

fig. 52: **Matrix of consensus (local-recreation system model, excerpt)**

that as soon as something happens in the system this variable changes very markedly. On the other hand, the fact that variable 8 ('Division by paths') has the low passive total of 7 means that a great deal has to happen in the system before this variable is affected.

Table of influence strengths

Assessing the matrix of influences makes it possible to draw up another table of influence strengths. In this the passive totals of individual variables are depicted with bars of proportional length in the left-hand column and the active totals similarly in the right-hand column. This shows at a glance which variables have the strongest effect on the system, which react most markedly to it, and which perhaps do both. This table offers another standpoint from which to view the results of the matrix of influences, serving above all as a supplement to the scale of influence indices discussed in the next section as well as to the tableau of role-allocation.

Assessing the influence index

But there are deeper questions that need to be asked of the system under investigation. Where are there potential control levers? Which components may jeopardise the system? In connection with which indicators is making improvements more analogous to treating symptoms? Which variables give the system a certain inertia that may possibly even absorb more marked changes? Simply being aware of active and passive totals

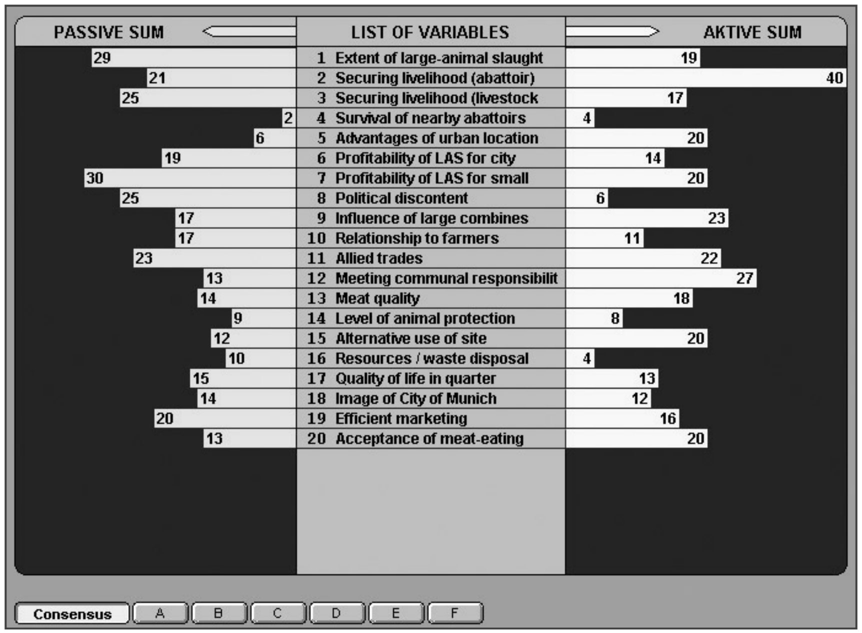


fig. 53: **Influence strengths** (large-animal slaughter in Munich system model)
The above example summarises the influence strengths emerging from a systemic investigation into large-animal slaughter in Munich. One interesting thing about this is that certain variables score particularly highly both to right (active) and left (passive). These include variables 1 ('no. of large animals slaughtered', 2 ('securing existence of abattoir'), 7 ('economic efficiency of large-animal slaughter for the trade'), and 11 ('associated trades'), which with every change not only exert a strong influence on the system as a whole but also react strongly to changes within it and are therefore termed crucial influence factors. The opposite case (namely, little effect upon the system coupled with a certain inertia vis-à-vis changes within it) characterises variables 4 ('continued existence of neighbouring abattoirs'), 14 ('level of animal-rights protection'), and 16 ('resources and waste disposal').

is not enough when it comes to answering questions like these. For instance, if an active component such as variable 11 ('Associated small and medium-sized businesses [SMB]') is itself strongly influenced by other components (as can be seen from a high passive total), it does not make a suitable control lever. On the other hand the active total of 20 shown by variable 5 ('Advantages of closeness to town') may play a very dominant role, whereas in connection with variable 7 ('Economic viability for SMB'), because of the very much higher passive total of 30 this is very definitely not the case. Only the relationship between active and passive totals (what we call the 'AT/PT quotient') reflects the active or reactive character of a variable.

However, if the question is asking how far a component plays a role in the system at all, how strongly it is involved in events, not even this quotient says enough on its own. For that, a second scale of influence indices is required, indices representing the product of each active and passive total. The bigger that product, the greater the role the relevant component plays in the way the system behaves (critical character); the smaller it is, the smaller the role (referred to as a 'buffering' role). And that is quite regardless of whether the component itself is more active or more passive. Moreover, simply adding together active and passive totals would not be enough. The fact is, even in reality it is the case (as any positive feedback loop shows) that, with each further influence on other parts of the system and the associated repercussions, actions and reactions do not simply mount up by addition; they multiply.

So if the product is so decisive as regards the role played by a variable, what purpose does the quotient serve? Well, quotients tell us whether, in a system, a variable has something to say or whether it has more of a listening brief, quite regardless of its strength. A higher quotient, even in conjunction with a small product, means that the variant concerned does quite clearly have 'something to say', even if it is 'under its breath', so to speak.

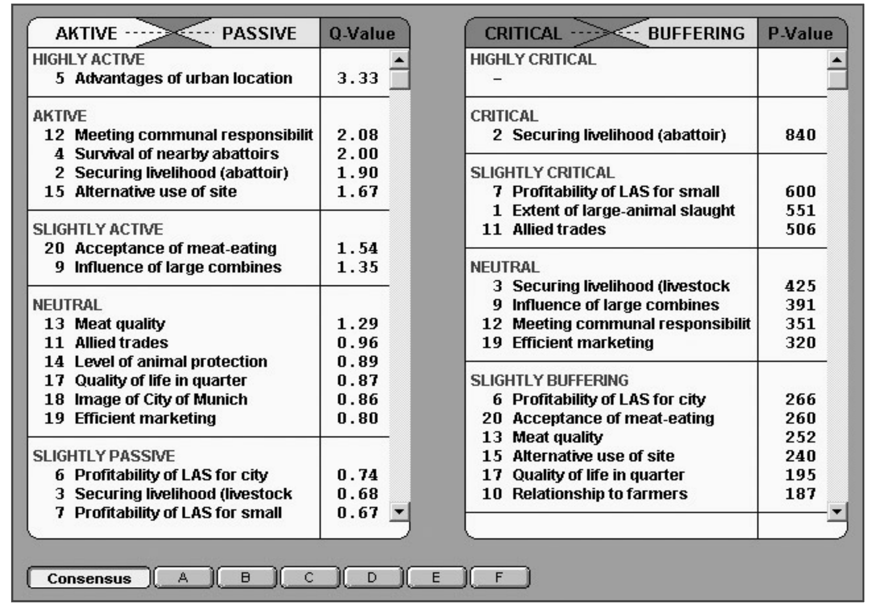
In this way the variables gradually acquire a system-relevant character. They turn out to be active, critical, buffering, or reactive, with all the intermediate stages between these four standards of value. Only their position in two fields of tension (between active and reactive on the one hand and between critical and buffering on the other) will show whether and in what fashion, in tackling the system concerned, intervention in a variable can and should be used. Precisely that position in the two fields of tension will be looked at separately in the next section but one, 'Allocation of roles', and interpreted as to what it has to say cybernetically. But the basis for this is consensus among the working parties involved regarding the assessments in the matrix of influences.

The matrix of consensus

When a project or planning proposal is discussed, a wide range of problems usually come in for consideration. Questions and solutions, wishes, arguments, and counter-arguments are put up and tend to be examined in isolation. The art of interconnected thinking is not at all about pushing one or the other argument through (a risk that we have already been able to reduce slightly by the steps undertaken so far); it is about capturing all the arguments objectively, so to speak, and incorporating them in a network of connections. It is then not we who are assigning the individual actuating variables to their rightful place and providing the correct decision-making aids; it is the system thus depicted doing so itself.

Dividing the assessment of influence into three distinct groups with, in each group, so far as possible, having representatives of different interests fill the matrix of influences jointly, also serves the purpose of avoiding over-rapid 'agreement' (through superficial arguments or better rhetoric) and subjecting divergent views, which usually remain intact from one group to the next, to re-examination. Errors of assessment or unclear definitions of one or another variable are thus uncovered jointly while the variables in question are defined in more precise terms or described afresh. In this way a genuine consensus concerning the final influence figures is reached very quickly.

Experience shows that, if a discrepancy arises, it is purely in the definition of specific variables, almost never in the assessment of their effect. It follows that reviewing the definition of a variable is an extremely important step – one that brings home to everyone involved (often much to their surprise) how widely people can differ (despite, for instance, working in the same department) in their understanding of



AKTIVE ---- PASSIVE	Q-Value
HIGHLY ACTIVE	
5 Advantages of urban location	3.33
AKTIVE	
12 Meeting communal responsibilit	2.08
4 Survival of nearby abattoirs	2.00
2 Securing livelihood (abattoir)	1.90
15 Alternative use of site	1.67
SLIGHTLY ACTIVE	
20 Acceptance of meat-eating	1.54
9 Influence of large combines	1.35
NEUTRAL	
13 Meat quality	1.29
11 Allied trades	0.96
14 Level of animal protection	0.89
17 Quality of life in quarter	0.87
18 Image of City of Munich	0.86
19 Efficient marketing	0.80
SLIGHTLY PASSIVE	
6 Profitability of LAS for city	0.74
3 Securing livelihood (livestock	0.68
7 Profitability of LAS for small	0.67

CRITICAL ---- BUFFERING	P-Value
HIGHLY CRITICAL	
–	
CRITICAL	
2 Securing livelihood (abattoir)	840
SLIGHTLY CRITICAL	
7 Profitability of LAS for small	600
1 Extent of large-animal slaught	551
11 Allied trades	506
NEUTRAL	
3 Securing livelihood (livestock	425
9 Influence of large combines	391
12 Meeting communal responsibilit	351
19 Efficient marketing	320
SLIGHTLY BUFFERING	
6 Profitability of LAS for city	266
20 Acceptance of meat-eating	260
13 Meat quality	252
15 Alternative use of site	240
17 Quality of life in quarter	195
10 Relationship to farmers	187

fig. 54: Index of influence (large-animal slaughter in Munich system model; excerpt)

terms that form part of their everyday vocabulary. Once people have agreed about what they understand by a particular variable, they will very quickly also agree about the strength of its influence.

It is precisely at this stage of the operation, then, that people once again come to see the system and its actuating variables from an entirely new angle. And since what are involved are neither problems nor solutions to problems but individual effects, even people who started out holding widely divergent opinions usually reach a common position before long. The matrix of consensus to which this gives rise serves as a foundation for subsequent stages.

Using the matrix of influence it is thus possible jointly to assess the interconnected effects of the elements of the system and hence the role they play not only from the standpoint of dominance (active) or susceptibility to influence (reactive) but also as regards the part they play in events (from buffering to critical). The role of the variables in the system becomes visible, and we learn for the first time, from the set of variables, what inherent forces the system possesses. This includes obvious effects, effects present at the moment of capture, but basically all the system's capabilities as they may arise *at one time or another* from the interconnectedness of its components as captured in the matrix. It might be called the system's genetic predisposition.

With this tool, too, the strength of the approach lies not in speculative forecasts but in throwing up possibilities as to how we need to shape and handle the system under investigation in order to make it react with maximum flexibility and capacity for self-stabilisation to such events as may occur. Knowing the influence indices, for instance, we may ask what the links between elements must be if (as in the Bad Aibling example) the 'mobility' variable, from being a buffering element, is to become an active one, or the 'quality of life' variable is to turn from being a largely reactive element to being a critical one. In this way we can anticipate how the system will react to unexpected developments. It becomes possible, as Arthur Koestler once said, to 'render the future well-disposed' instead of, as is the case in connection with the traditional kind of pseudo-forecast, at best 'repairing' the consequences of wrongly anticipated developments.

Role allocation

A good way to represent the role of each variable in the system is a two-dimensional diagram in which the current position of a variable between the four key roles (active, reactive, critical, buffering) can be seen at a glance and properties can be assigned to it accordingly. Since all variables will lie somewhere on the axes of coordination 'active-reactive' and 'critical-buffering', this mode of portrayal offers a comprehensive if somewhat approximate overview of the different distributions of roles in the system; because the concrete interpretation must of course also take account of the various blends in the role of a variable. For instance, it makes a huge difference whether an active factor is at the same time located among critical or among buffering elements. In the former case, influencing this variable will have a destabilising effect. In the latter, it will do the opposite; it will bring stability. The table of role allocation with its grid of straight lines and hyperbolas is divided into 50 different colour fields between the four standards (arranged in a cross) of 'active' to 'reactive' and 'critical' to 'buffering'. In this dual field of tension, each variable occupies a position (ascertained by a computer) on the basis of the value placed upon it in the matrix of influence and on the basis of the total number of variables.

In this way, distributing the variables gives an immediate impression of the character of the system as a whole, which may turn out to be generally critical, for instance, or on the contrary particularly inert. Moreover, as regards interpreting the roles of individual variables, in the computerised version of the Sensitivity Model each of the 50 colour fields receives a general description matching its position, and this can already serve as a cybernetic strategy indication. Since the position of a variable is always a product of the overall interconnectedness of the network, such a statement comes not from the person studying the sys-

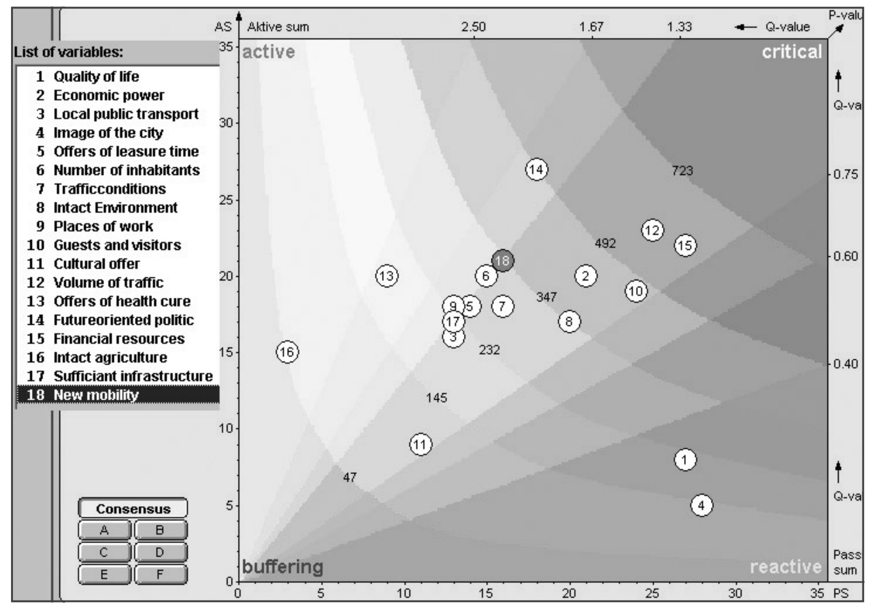


fig. 55: **Allocation of roles (Bad Aibling system model)**
The radial dividing-lines correspond to transitions from highly active to strongly reactive, as measured on the scale of the index of influence, the hyperbolas of transition ranging from markedly buffering to highly critical. The central rectangles correspond to the neutral area.

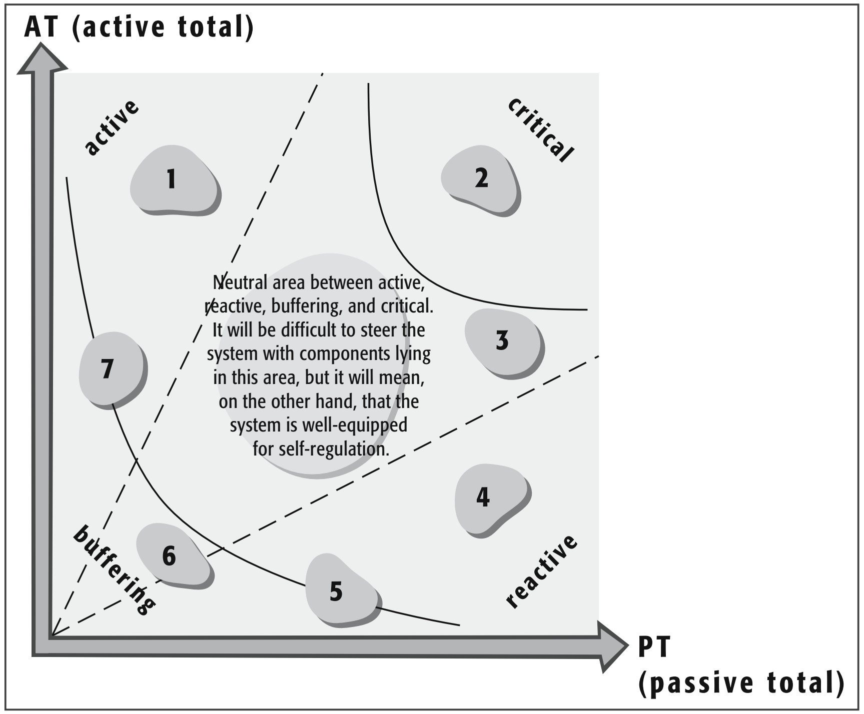


fig. 56: **To interpret allocation of roles**

1. Here are effective control levers that will re-stabilise the system once a change has occurred (three-dimensional stability).

2. Here are accelerators and catalysts, suitable for firing up in order to get things going at all. Uncontrolled rocking and tipping are possible, though, so extreme caution is called for (the 'velvet-glove' approach).

3. It is particularly dangerous if associated clusters of variables lie in the critical/reactive area.

4. Intervening here to steer things will produce only cosmetic corrections (treating symptoms). However, these components make excellent indicators.

5. Somewhat sluggish indicators, but they can also be experimented with.

6. Area where interventions and controls serve no purpose. However, 'wolf-in-sheep's-clothing' behaviour is also possible here if one proceeds incautiously or abruptly oversteps thresholds or limits.

7. Here are weak control levers with few side effects.

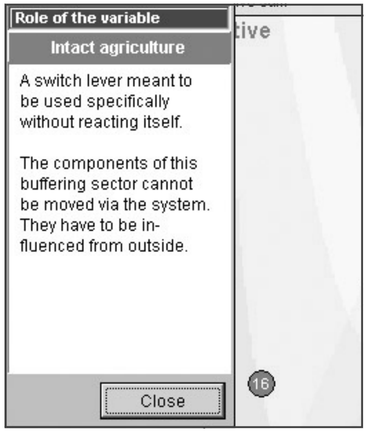
tem but from the system itself, as captured thus far.

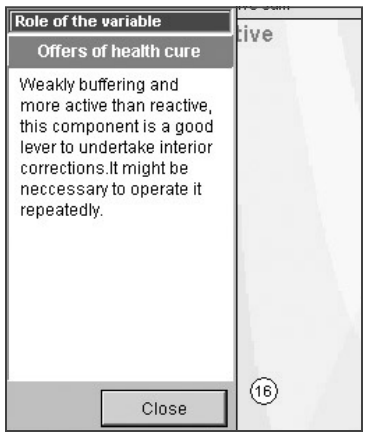
Clicking on a variable in the role-allocation table will immediately show what role that variable plays in the system. For instance, in the table from the 'Bad Aibling' system model (fig. 55), clicking on variable 4 ('Image of the town') will supply the message that this is a reactive-buffering element '. . . in which changes to the system are reflected (sensors). The temptation is therefore to intervene in a direct, controlling manner. This can only obscure the situation and will at the same time result in unexpected side effects.'

As the following excerpts from the Bad Aibling project show (fig. 57a and 57b), the position of variable 16 ('Intact agriculture'), which lies more in the reactive-buffering zone, already results in a quite different statement than in connection with the slightly higher-placed variable 13 ('Spa-cure supply'). The respective interpretations are based on our years of experience with the most widely varied system investigations. Thus each field contains a generally valid cybernetic explanation for the variables found in it, an explanation that depends on the nature of the system under investigation. That explanation is assigned not to the variable itself but (typically of the interconnected approach) to its position in the specific system. In a different system, the same variable would probably occupy a quite different position.

In the example of the Bad Aibling system model, inclusion of variable 18 ('New mobility') as a further component of the system procured a particularly impressive effect. With the help of the strategic indication provided by role distribution, the system now revealed previously unrecognised possibilities of systemic control and hence of changing the situation complained of. This outcome then received further confirmation from other directions (namely, as a result of the regulatory-cycle analysis to be discussed in the next chapter – and last but not least through the actual situation in Bad Aibling itself).

The 'role allocation' stage of the operation still characterises the individual variable, but simply locating the position of that variable in the role-distribution table furnishes an authentically systemic statement, since that position comes about only as a result of all the other variables also being involved. Moreover, the process of allocating role to variables provides improved information about the sensitivity of the system as a whole.





figs. 57a and 57b: **Role of individual variables (Bad Aibling system model)**

While the 'matrix of influence' and 'role allocation' stages of the operation have revealed the latent predispositions of a system in regard to the cybernetic roles of its variables, in the next chapter (which presents the 'effect structure' tool) we start to track down actual sequences of events, interconnections, and feedback processes.

15 • Effect structure, partial scenarios, and feedback controls

Having reached this stage, we know about and are familiar with the individual components of the system and the role they play in it. On the other hand we are unaware, as yet, of their *specific* interplay and, tied up with that, the complex pattern of the system, its stabilising tendency, its limits, and its irreversibilities. All this we learn only when the variables are interconnected in the form of an effect structure with which we can build what might be termed a 'macroscope' of reality.

Since that reality consists not of heterogeneous individual components but is an interconnected structure of effects and repercussions (although the connecting threads are invisible to us), the structure usually behaves quite differently from the way we might predict after simply studying its components. A model of reality, however, ought to allow for that fact. The tools of the next stage of the operation enable us to visualise the invisible threads linking the components and build into the model further levels going beyond the traditional cognitive image – an important step in training and applying interconnected thinking. Because when it comes to capturing reality in all its complexity and overlapping levels, we can do nothing without the right toolkit. What we call 'parallel processing' of complex chains of events is something we achieve with the right-hand half of our brain (through intuition, pattern recognition, and analogy); we cannot achieve it with the left-hand, abstract-verbal half. We need the latter, though, if we are to objectify complexity, work with it, and communicate it to others.

What the matrix of influence tells us results from our analysing bilateral effect connections and tends to characterise the way the system basically behaves and the role played by the variables, whereas an effect structure should render the system's chains of effect and feedback loops visible, reflecting present reality in its multi-dimensional interconnectedness.

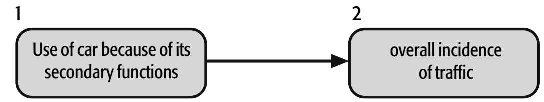
Effect structure asks different questions from matrix of influence

For the purposes of building up an effect structure, the links between variables are examined differently than in connection with the matrix of influence. There it was a question of the different strengths of potential effects that might be triggered by changing the initial variables; in connection with building up the effect structure, on the other hand, it is not the links between variables that might become active at some time in the future that are discussed and noted but those that are in fact active currently. As a result, sometimes different and above all far fewer links are registered than is the case with the matrix of influence. This is also why an effect structure should be built up so far as possible independently and not constitute simply a pale imitation of the matrix of influence. The aim, after all, is for each stage of the operation to show the system from a different standpoint and be constructed in as impartial a way as possible in order to correct any errors that may have crept in previously.

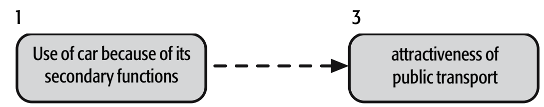
The diagrams on the next few pages show a further difference from the matrix of influence. This takes the form of dotted or continuous effect arrows between variables. Such arrows indicate not different strengths of an influence but the direction in which that influence exerts its effect: whether a rise or fall in the starting variable also makes the end variable rise or fall (link in the same direction = continuous arrow) or whether that effect operates in the opposite direction (= dotted arrow). Where two or more variables exist in a reciprocal relationship, we talk about 'feedback'.

The technique of representing the feedback loop

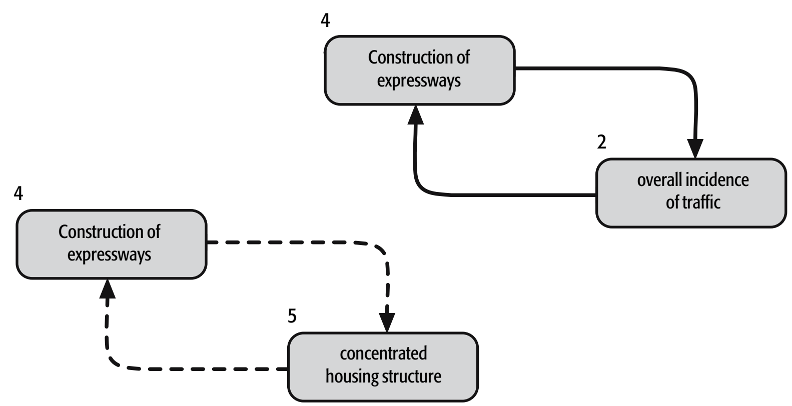
Some people are less familiar with the way interconnectedness is represented diagrammatically, so in order to cater for them as well here is a further explanation of how the basic elements of a feedback loop or regulatory cycle are shown, using a concrete example:



A continuous arrow (as here between variables 1 and 2) stands for a link *in the same direction*: more cars, used as status symbols, make more traffic; fewer make less.



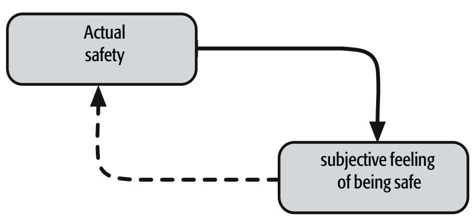
A dotted arrow (as here between variables 1 and 3) stands for a link *in the reverse direction*: the more the car is used as a status symbol, the less the attractiveness of public transport; the less status plays a role, the more likely people are to switch to public transport. If there is now an effect in the opposite direction, we talk about feedback. Where two arrows of the same kind are involved, what we have is positive feedback.



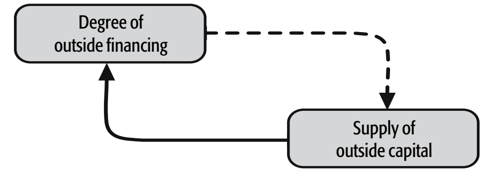
There are two kinds of positive feedback. In the first kind (as here between variables 4 and 2), two continuous arrows indicate that two variables mutually reinforce each other in the same direction; furthermore, depending on the initial impulse they do so both in the one direction (the two start rocking more and more violently) and in the other (the two of them shrink ever faster) – in both cases, only up to a certain point, of course. In the second kind of feedback (the kind shown happening here between variables 4 and 5) two reverse connections are harnessed together. Again, the result is an unstable relationship, a self-reinforcing positive feedback. Depending on the starting situation, one variable starts rocking at the expense of the other. In our case, the connection leads either to the building of more and more expressways coupled with fragmentation of the municipal residential structure, as a result of which yet more roads become necessary, or conversely to a consolidation of local residential structure, brought about by removal of expressways, establishment of pedestrian precincts, and further road removal. Variables 4 and 5 drift apart, as it were.

If on the other hand the two effects are of different kinds, the result is called negative feedback. As explained earlier in connection with the eight basic rules, negative feedback loops are particularly interesting as suggesting the presence of self-regulation. They have the property of absorbing changes or converting them into a pendulum movement, and in an interconnected system they should predominate over positive feedback loops if the system is to remain stable in the face of disturbances. In living systems, positive feedback loops tend to be rare, though they are still necessary since they set developments in motion. They often exist at the start of evolutionary stages.

Negative feedback is different: it can lead to logical wrong conclusions. In our studies to do with traffic safety, for example, we found that because of negative feedback technical safety measures did not necessarily lead to increased safety but that the risk of accidents remains virtually constant:



Soon after the introduction of ABS (the 'anti-blocking system' for brakes), the projected bonus on insurance premiums for vehicles fitted with them was withdrawn.



Exactly the same thing happened in another case from the sphere of risk management, where a reduced degree of financing from outside sources makes a lot of outside capital available. If as a result of use of this the degree of outside financing and hence of indebtedness rises, investors will be reluctant to make further capital available. That kind of muffled oscillation then leads the system towards a state of equilibrium.

In building up an effect structure it will once again be necessary, initially, to proceed by hand and (independently of the already existing matrix of influence) draw up a list of the same-sense or reverse connections stemming from each variable. With computer-assisted graphic aids, actually building up an effect structure is quite simple. The structure can also be re-arranged very easily without any links being lost. This gives access for the first time to a coherent model of the visible network of variables from which (provided the right software is being used) all information captured up to now can be summoned at the click of a mouse and as easily corrected or added to. Essential interconnections and points of emphasis can be spotted immediately by the number of entries and outcomes of individual actuating variables, while for evaluating the network of feedback loops that govern the way the system behaves in the long term, a special tool needs to be resorted to. As can be seen from the list of regulatory cycles given below (see fig. 59), a wealth of overlapping positive and negative feedback loops can appear.

Since the interplay between them cannot possibly be followed by eye, this is where the sensitivity-model software comes in useful with its own analysis of regulatory cycles. Calling up the automatically ascertained feedback loops reveals at a glance whether, for instance, in a particular effect structure negative feedback loops and hence self-regulation prevail or whether with positive feedback predominant the structure is in jeopardy.

Regulatory cycles as indicators

The number of feedback loops, which depending on the system can vary enormously, itself says a certain amount about how the system will behave. A small number of feedback loops tends to suggest a 'flow system' dependent on external factors, while a system with many feedback loops is probably one with a more self-sufficient type of behaviour. The length of the effect chains gives further important hints. 'Long' feedback loops (having many intermediate stages) mean repercussions with a time lag. Because they are usually noticed too late, such repercussions can be dangerous. On the other hand, 'short' regulatory cycles between two or three variables usually point to a swift reaction. In the case of negative feedback, this means establishment of a state of equilibrium; in the case of positive feedback, it means a rapid build-up of violent rocking. Here it makes a crucial difference how such 'short' or 'long' cycles are distributed among negative and positive feedback loops.

Moreover, analysing regulatory cycles reveals which variables can be built into an effect structure with feedback loops and which without. It also shows whether certain variables may perhaps be connected only amongst themselves, forming an isolated partial system that depends on the system without having any effect upon it. Moreover, it is possible, by tracing the effect flows of individual variables (which can if necessary be brought out by the click of a mouse), to discover the principal nodal points of the system as well as its starting or target variables and those that merely represent transit stations. Degree of interconnectedness, flow, and dependency are thus basic cybernetic index factors that in connection with evaluation according to the eight biocybernetic basic rules give important indications of a system's viability. As regards future strategy, there are often surprising course-setting possibilities to be found here.

As an example of the partly regulatory, partly self-reinforcing interconnectedness of complex processes, let us take an effect structure covering the long-term connection between the economic activities of the human race with the climatic changes discussed earlier in this book. A previous chapter showed how the exponential increase in the amount of carbon dioxide in the atmosphere is coupled with a measurable rise in

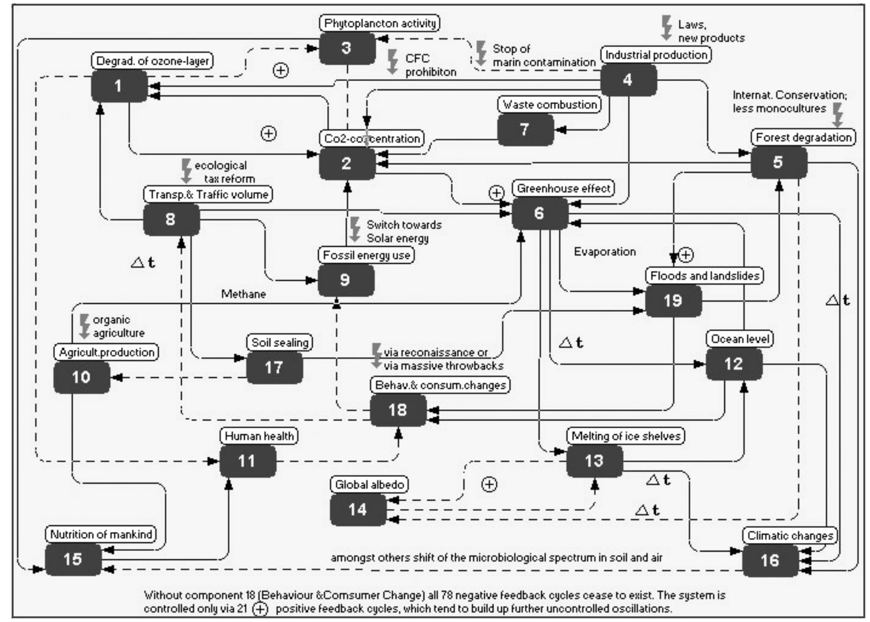


fig. 58: **Climate network** (climate system model)

average world temperature and that this greenhouse effect has already led to perceptible changes in the climate (more frequent storms, floods, forest fires, failed harvests, landslips) as well as to an exponential rise in insurance losses.

The effect structure illustrated as fig. 58 contains 21 key factors that play a role in the greenhouse effect and its consequences, represented together with their interactions. As well as chains of effect this also shows a large number of feedback loops. The latter include some that regulate the system through cushioning effects and others that set it rocking violently as a result of self-reinforcement, with the interplay of the two saying something about the way the system will develop in the long-term. In our example, the total number of feedback loops is particularly high, possibly because they are strongly interconnected.

The list shows 54 negative and 30 positive feedback loops, so here is a system subject to a great many regulatory forces but with all the 'short' cycles (i.e. those that involve only a brief time lag) to be found among what tend to be the more destabilising feedback loops. Altogether,

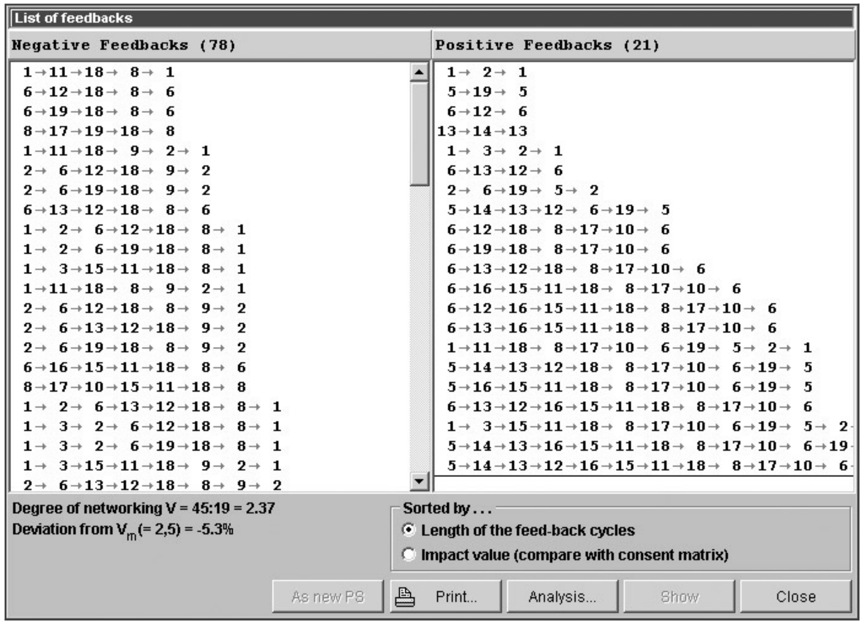


fig. 59: **List of feedback control loops** (climate system model; excerpt)

though, the system looks as if it can be changed only slowly according to this model.

Now, in order to find out which variables deserve particular attention because of their involvement in the structure we use regulatory-cycle analysis. The most frequent involvement in both types of regulatory cycle is shown by variables 18 ('change of behaviour'), 8 ('incidence of traffic'), 6 ('greenhouse effect'), 2 ('concentration of CO2'), 11 ('human health'), and 16 ('climate shifts') – to mention the six most strongly interconnected.

To learn the importance of individual variables as regards the interplay of reciprocal effects, you can cause as many of them as you like to 'fade out' from the model – in other words, you can pretend that (to name three examples) traffic stress no longer existed, no further carbon dioxide was being released into the atmosphere, or no more forest was being cut down. In connection with each analysis, the number of feedback loops and the ratio of negative to positive ones will of course vary each time.

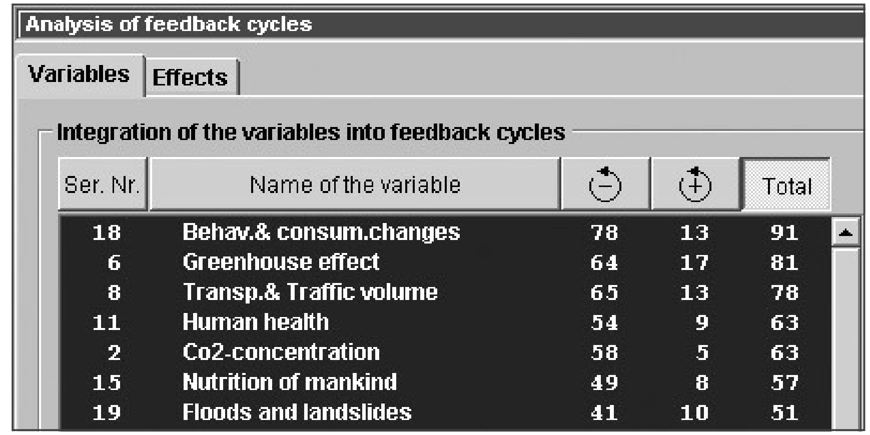


fig. 60: **Analysis of feedback control loops** (climate system model; excerpt)

The astonishing thing is that, by experimentally taking out individual variables, you can intervene at every possible nodal point of the climatic structure without the network as such exhibiting major changes. Only one variable constitutes an exception in this connection, creating a completely different situation, and that is variable 18 ('change of behaviour'). If variable 18 is extracted, all 54 negative feedback loops and thus all stabilising negative regulatory cycles as well as 23 of the positive feedback loops no longer have effect. The system is then controlled only by seven 'short' positive feedback loops that would set the system rocking violently until it overturned. Among the remaining variables there are no stabilising regulatory cycles left. Such a system develops in an uncontrolled manner and is greatly at risk.

All regulatory negative feedback loops that might prevent the system from collapsing accordingly operate through variable 18, 'change of behaviour'. As regards interpreting the climate network, this means that (for instance) technological support alone, wherever applied, would not halt the rocking process. Without a complete upheaval in use of resources, mobility, land use, and use of energy, climate change would continue at a faster rate.

According to this effect structure, the lever for avoiding such a development clearly lies within variable 18; it involves our consumer behaviour

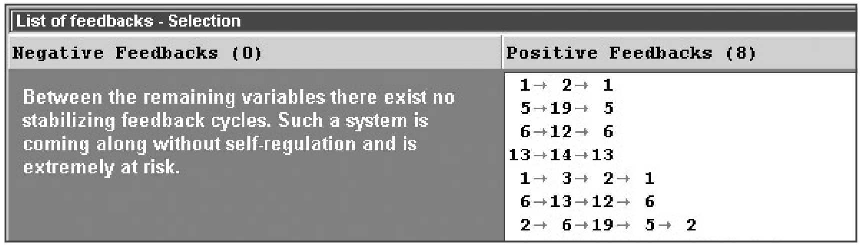


fig. 61: **Report of discontinuation of variable 18** (climate system model)

and our priorities undergoing a change. The sooner this happens and the sooner the regulatory feedback loops come into play, the less far the rocking process will go and the gentler the transition will be, with no loss of affluence and quality of life. The later the change of behaviour occurs, the more brutal the transition will turn out to be, and at some time massive setbacks will force us to change. It follows that an unsparing campaign of public education about these connections is urgently needed, with politicians and economists joining in. The process has begun, not just with the appeals of the climate conferences of recent years but also with the introduction of EU standards ISO 9,000 and ISO 14,000 and with Agenda 21 – but it is proceeding very hesitantly.

A study by Bernhard Flückinger of ETH (Zürich's technical university) of the repercussions of the greenhouse effect has said: 'The Sensitivity Model provided a suitable approach for modelling interlocking repercussions of climate changes and natural disasters. In contrast to alternative approaches, it offers a special advantage: its cybernetic methodology takes account of the holistic character of systemic structures and means that non-quantifiable factors (risk perception, the quality of the cultural landscape) can also be modelled.'

Let us turn to a different, less dramatic example: the effect structure in the Bad Aibling project, which provided decisive assistance for a piece of communal decision-making. Role allocation having already demonstrated that the existing system ('traffic relief') offered few active and reactive variables and tended as a whole to be located in the buffering zone, as an additional component the variable 'new mobility' was taken into the set of variables and a new matrix of influence drawn up. Now that allocating roles gave rise to a quite different picture (see above, p. 237), the effect structure too was promptly drawn up with the same variables.

Regulatory-cycle analysis of the effect structure reproduced consequently showed a good mixture of 29 stabilising regulatory cycles and 37 positive feedback loops as the 'engines' of the development aimed at. The picture changed abruptly when the 'new mobility' component was once again extracted from the network. The original 'where we are now' state then exhibited, in addition to 17 negative feedback loops, only 2 positive feedback loops, suggesting a situation that scarcely moved at all – exactly what had been the case in Bad Aibling for many years.

Recognising the need for action within the town was then also the occasion for coupling construction of a by-pass with traffic-calming measures (under the 'new mobility' slogan) being introduced simultaneously in the town centre. This process was pursued energetically and with great success, not least because the whole municipality was indeed behind the Sensitivity Model, it having been worked out jointly.

Partial scenarios

In order to subdivide a system model further, to open it up, so to speak, and get closer to the system's internal cybernetics, in the next stage of the sensitivity process particularly interesting parts of the effect structure are excerpted and built up as partial scenarios. The emphasis here is on linking each variable more firmly to its concrete effect and examining that effect in terms of reality. Depending on how the questions are put, the effect structure of a system model can be 'picked apart' for this purpose into a number of partial scenarios. Their coherence with the overall effect structure of the system is not lost in the process because the partial scenarios not only proceed from this but also overlap.

The choice of the variables required is not so much governed by hierarchy and by their belonging to specific parts of the system; rather, the immediate starting-point is formed by concrete questions of particular thematic interest. Some variables can be broken down into sub-variables for this purpose and described in greater detail. Auxiliary variables may be inserted and connected up accordingly. However, quantifying

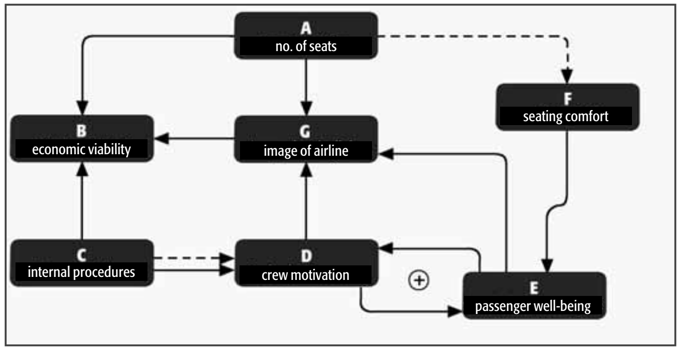


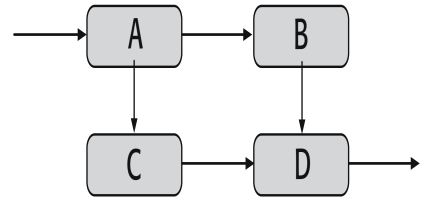
fig. 62: **Swissair effect structure** (partial scenario)

the variables more precisely is less important than establishing their environment, their relationship to one another, and the pattern of their effects upon one another. In this way partial scenarios (together with what they say) form an essential component of the Sensitivity Model; they bring us directly to the way the system behaves and hence to the 'mechanics' of the cybernetics operating within that behaviour.

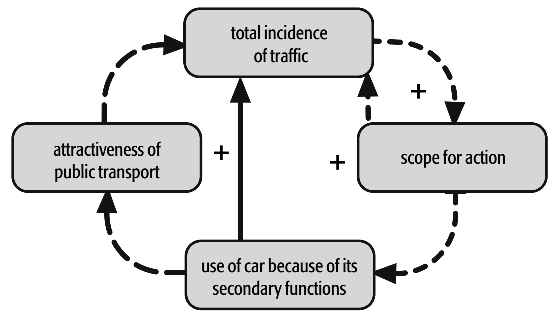
For instance, in the course of a sensitivity analysis it took only a simple effect structure to make the Swissair planners aware that in connection with their 'passenger cabin 2000' project it was not so much a question of optimising individual factors; the most important things were the interplay of the factors passenger, crew, technology, and organisation and the cybernetics of that interplay. 'We had gone as far as we could in optimising individual factors,' qualified engineer and manager of the Engineering Projects Division Peter Hablützel explained to the [German] business journal *Management Wissen*. 'Only with the help of the Vester Method did my colleagues and myself learn that an airline cabin is an extraordinarily interconnected system (like a biotope) in which a change in one individual element can set off a chain reaction with unexpected consequences.'

Partial scenarios have an organic function

A partial scenario should comprise between two and ten variables – no more, if possible. Small partial scenarios made up of three or four varia-



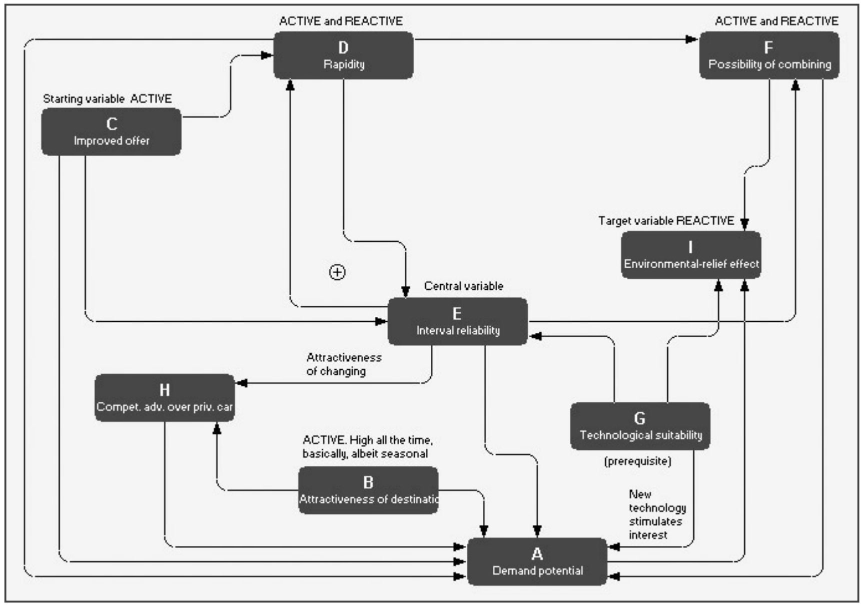
bles can very often possess extremely clear cybernetic functions; furthermore, when taken over in the 'simulation' stage of the operation, these can very often be explained more precisely in terms of their dynamics. Since even in the most complicated effect structure each regulatory cycle can be ascertained immediately, using the tool already described, and emphasised by simply clicking on it, here too particularly interesting feedback loops can be analysed in terms of their function as 'organs' of the system as a whole. While many such associations depict only stations along a flow path (see diagram alongside) and exhibit no feedback of any kind, others have a markedly cybernetic character. This is the case in the following example, in which some of the already familiar variables



from the world of traffic are linked together in such an 'organ', which consists of a pyramid of three positive feedback loops and therefore, because of its instability, represents a critical nodal point of the system.

In analogy to living systems, the systemic 'organism' reproduced in the overall effect structure might be said to comprise a series of 'organs' having different functions and consisting in turn of individual 'cells' (the variables), which are themselves composed of 'organelles' (the indicators and quantities from the description of the variables).

The mechanisms discovered make it possible to see the cybernetic connections in the areas investigated. This then leads almost spontaneously to new, possibly unfamiliar, but now plausible solutions to problems and instructions for action. This not only serves to find out what is undesirable or dangerous (critical quantities, violently rocking feedback loops, dependencies colliding with limits); it also, in the constructive sense, renders visible the truly effective starting levers and opera-



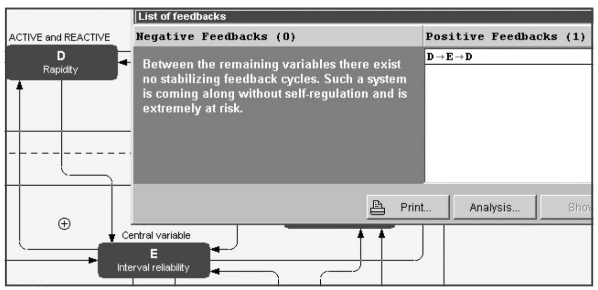


fig. 63a: **Express bus/Technology and Logistics I** partial scenario ('Emissions-led traffic-calming plan for southern Oberallgäu' system model)
fig. 63b: **List of feedback cycles**

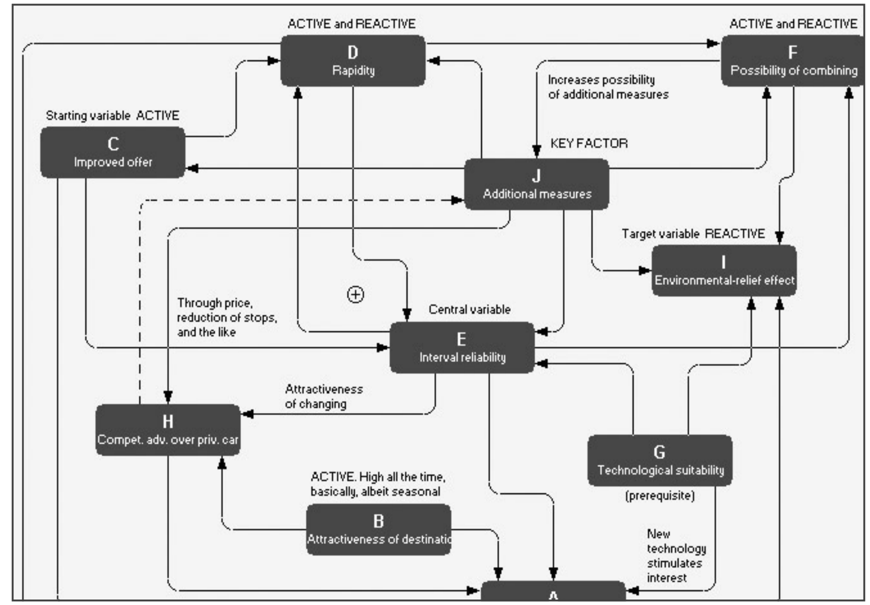
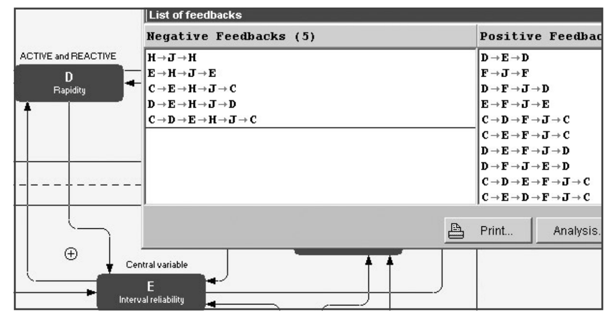


fig. 64a: **Express bus/Technology and Logistics II** partial scenario following involvement of 'additional measures' variable (southern Oberallgäu system model)
fig. 64b: **List of feedback cycles after involvement of new influence factor**



tors for improving the systemic situation.

In this way each partial scenario at the same time evolves into a sort of policy test with which the most diverse situations are tested, which is why they are also described as 'what-if' scenarios. Different 'what-if' developments are played out in that, for instance, individual variables constituting possible control levers are changed and the interconnected effects thus introduced are allowed to run their course in the system.

In connection with a traffic project carried out with the Sensitivity Model in the South German Upper Allgäu region, one thing that emerged was that introducing new traffic measures was at risk from tipping-point effects. Analysis of one partial scenario (fig. 63a) shows a single positive feedback loop (fig. 63b), which is to say that for practical purposes there is neither pulse generator nor stabilising regulatory cycle. Accordingly, proposed traffic-calming measures are hard to get going and will probably be abandoned at the slightest upset – as is often in fact the case.

Only by tying in the actuating variable 'additional measures' (fig. 64a) is sufficient self-reinforcing feedback built up and the requisite motors started to set a fresh development in motion (fig. 64b). At the same time the additional measures are protected by regulatory cycles against both over-steering and reaching a tipping-point. Concrete events also showed that this prediction of the model was sound and that such (usually inexpensive) additional measures as 'clear signing', 'comprehensible synchronised timetables', and 'public relations' were more decisive determinants of a project's success than many a costly main measure.

16 • Simulations and policy tests

Simulation in a Sensitivity Model helps to provide a deeper understanding of system cybernetics. It examines not only how the system reacts to the removal or insertion of a variable but also how far subtler interventions – a change in the state of a variable, say (an increase in 'sales figures' through advertising or a decline in the 'attractiveness of the landscape' in consequence of a motorway access road, etc.) – will affect the system. It also offers a way of recording the consequences of a change in the relationship between two variables over time, as happens in connection with car production, for example, between the 'performance of a supplier' and the installation consequence on the production line as a result of the improved flow of information. Accordingly, simulation is an interactive tool for researching interconnected dynamics. In what we call 'policy tests' it is possible, by comparing different simulation processes, to examine what consequential effects changing a 'control lever' or a 'critical component' has on the entire network of the partial structure, whether the desired effect will perhaps be cancelled out, whether it reinforces itself or eventually tips over into the opposite, and where the associated limits and thresholds lie. To enable the policy tests and 'what-if' processes to be checked by insiders as well as by outsiders, it was essential to design the didactics of the software in such a way as to make the whole tool transparent and to render the way its predictions come about comprehensible to the lay person as well.

Partial scenarios as basis

The 'simulation' stage in the Sensitivity Model is based on partial scenarios. It therefore never simulates the whole system model, only parts thereof. It is particularly concerned with visualisation and with following up individual chains of effect and regulatory cycles. Since each individual feedback loop can be highlighted separately, it is possible to go

further than that and to extract the interesting interconnections and incorporate them in the simulation tool in order to test them for their cybernetics and their effect on the rest of the system.
Without simulation it is scarcely possible, for instance when a negative feedback loop is connected with a positive one, to decide which of the two is dominant, i.e. to represent the superordinate regulatory cycle. The question of whether a weak feedback loop having a direct effect is more important here than a strong one that takes effect only with a time lag is also best explained by running a few simulations. Two things are important in this connection: functional descriptions that are always plausible (and that are entered in their allotted text boxes promptly, as each relationship curve is constructed) and making the connection thus described transparent for everyone.

System cybernetics as long-term behaviour

Every complex system has a time horizon within which it behaves almost like a machine and can still be regarded as a closed system. Consequently, it is only possible, as discussed in chapter 5, to make meaningful forecasts even with so detailed a simulation up until that time; beyond that time horizon there is no point in using simulations to predict whether or not certain events will occur. In growth phases and for short time horizons, even complex systems permit certain prognoses and will, in the eyes of the ignorant, reflect a deterministic development. This encourages the kind of wishful thinking so dear to futurologists and economic forecasters to the effect that they can to say in advance precisely how complex systems will develop; it diverts attention from the real and far more meaningful potential of cybernetic systems analysis as long-term decision-making aid. However, the kind of system cybernetics captured by a 'fuzzy' simulation, which provides information about regulatory cycles, feedback loops, critical or reactive areas, limits, and the like, holds good only for extended periods of time. Rather than predicting the course of events, it will tell you how a particular system will behave and about the way it will react to specific occurrences.
But what are the prerequisites for that kind of systemic simulation?

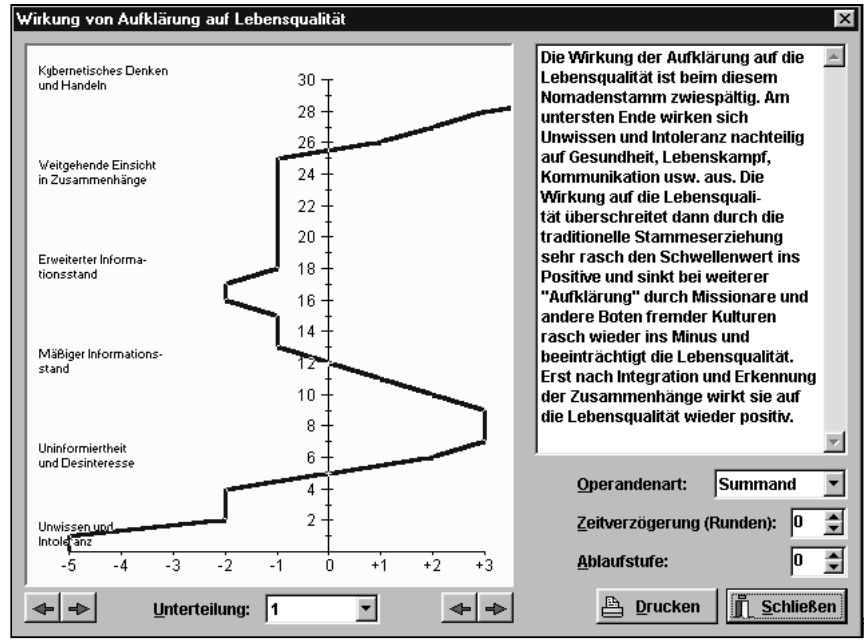


fig. 65: **Simulation** (nomadic tribe system model). As a typical example of a non-linear table function we have here chosen the effect of 'public-education measures' on 'quality of life' in a developing country. It gives an almost chaotic impression although the plain-text explanation suggests that it will follow precisely this course. Another reason why verbal description of each effect curve is important is that it supplies a good basis for an explanatory discussion with insiders.

The prevailing view is that only with precise data can a simulation programme be brought into a mathematical system of relationships; with qualitative factors, factors that cannot be measured, nothing can be done. As we have already stressed on many occasions, the opposite is true. The fact is, if the (equally real) qualitative factors are removed from a situation, the result will certainly not chime with reality. If on the other hand qualitative data are included in a fuzzy simulation, they will guarantee that, although the concepts of reality they offer may be imprecise to a greater or lesser extent, those concepts will never be false. If the degree of imprecision is so great that even the model of reality is no longer right, the mathematics of fuzzy sets will delete it – in complete contrast to precision models, which even if they are completely wrong will still look precise.

Building on the work of Lotfi Zadeh, Hans-Jürgen Zimmermann, Hans Werner Gottinger, Joseph A. Goguen, and others, we were able to design the Sensitivity Model (one of the first system models) in such a way as to make it possible, by using fuzzy logic, to blend qualitative with quantitative data and still include both in a network of connections that could be predicted for simulation purposes. This way of going about things is necessary for systemic simulations if only because in reality most links between two variables are in any case predominantly non-linear as well as not susceptible of mathematical treatment. In linear, logarithmic, exponential, or asymptotic terms or as a sine curve they proceed only in certain curve sections (and in such phases can very well be described by means of a formula); in other areas, however, they tip abruptly or persist in the same state for long periods.

The mathematical background

The understandable difficulties of a simulation lie in the complex interplay of a number of variables and in rendering that interplay in a mathematical model that can be drawn up by the user as simply as possible yet should still reflect the way things actually are. It seemed to us important in this connection to depart from the usual way of portraying a simulation, which hides its algorithm behind mathematical functions and differential equations in such a way that no one can understand the thinking behind it. In the end, traditional simulations never cease to be 'black boxes'. With the aid of fuzzy logic, at least they can be turned into 'grey boxes'.

The links that in the case of the Sensitivity Model underlie the effect curves of a simulation are therefore table functions; in other words, they correspond not to unambiguous formulae such as y = f(x) but to a table of reciprocally allocated, discrete (non-continuous) numerical values. Since what we are dealing with here are dynamic effect structures, there are also no fixed relations between components of the system. It follows that the curves do not reflect the position of (say) environmental pollution at a certain level of production but the contribution that a certain level of production makes at each round of the simulation process towards environmental pollution – regardless of the level of such stress at any given moment. As can be seen from the screenshot reproduced as fig. 65, the vertical scale of the y-axis (calibrated from 1 to 30) always shows the state ranges of a variable between the lower and upper extremes. The strength and direction of the effect proceeding from that variable on the target variable concerned are shown on the x-axis, while to the right there is an explanation regarding the course of the curve at issue.

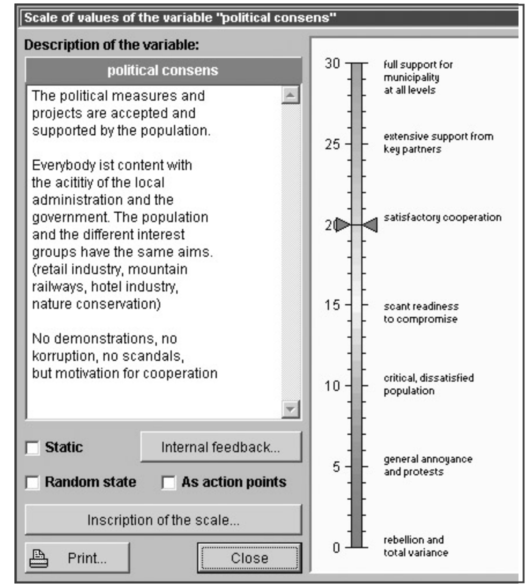


fig. 66: **Scale of value of 'political consent' variable** (Oberstdorf system model)

Programming the course of events

On the basis of an effect structure drawn up at the 'partial scenario' stage of the operation, the user needs to do only four things before running the first simulation:

1.- He/she must scale the variables and grade them according to their current starting-value. When each variable is assigned to its place on a scale of value, this numerical scaling will be supplemented by a verbal description of the various states between the two extremes. Only such verbal characterisation of the bandwidth will render the manner in which the variable changes plausible to the person using the model and allow a discussion to take place about the associated effect of one variable on another.

2.- He/she must express the effect arrows in the form of table functions. Clicking on an arrow will make its function tableau appear, and on this, again with the aid of the mouse, the course of the effect can be drawn in directly (it can also be changed at any time), and the resultant curve of the table function can be justified in a description (see fig. 65). The character of a connection (whether running in the same or the opposite direction), already roughly ascertained in the partial scenario, will be further differentiated by the nature of the effect curve. Since in this way the functions will remain transparent for all, they can be re-examined at any subsequent time by experts or by those concerned.

3.-He/she must set the clock pulse for a run-through at a common denominator.

4.-And he/she must indicate the sequence of the effect flow through the partial system.

As our example, we choose a simulation scenario from our system study for a traffic-calming project in Oberstdorf municipality.
As always with controversial projects, among the things needing to be ascertained was whether and to what extente/consensus within the municipality influenced its further implementation. In the present-state tableau of the 'political consensus' variable, the position of that variable can now be set to specific ranges in order to simulate developments and obtain strategic indications.

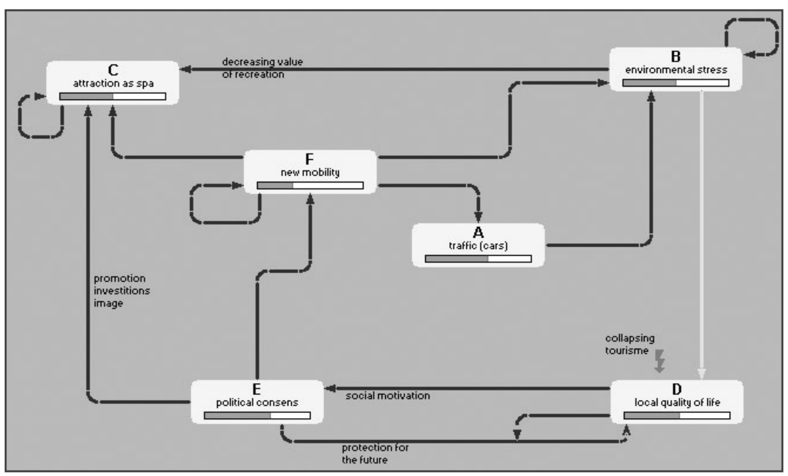
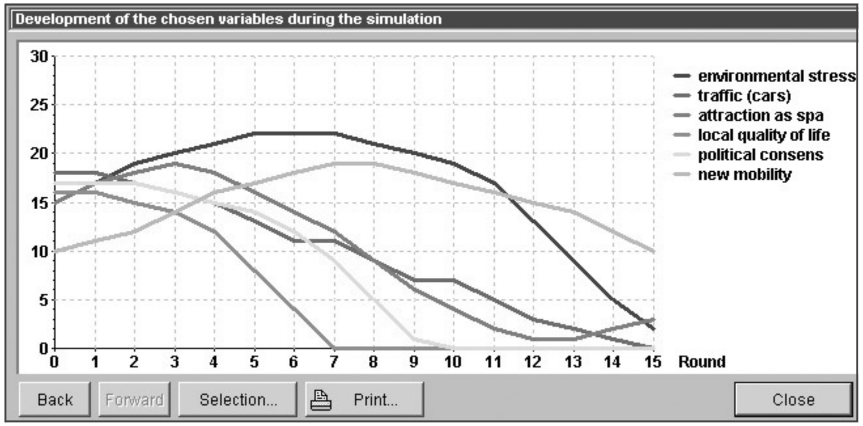
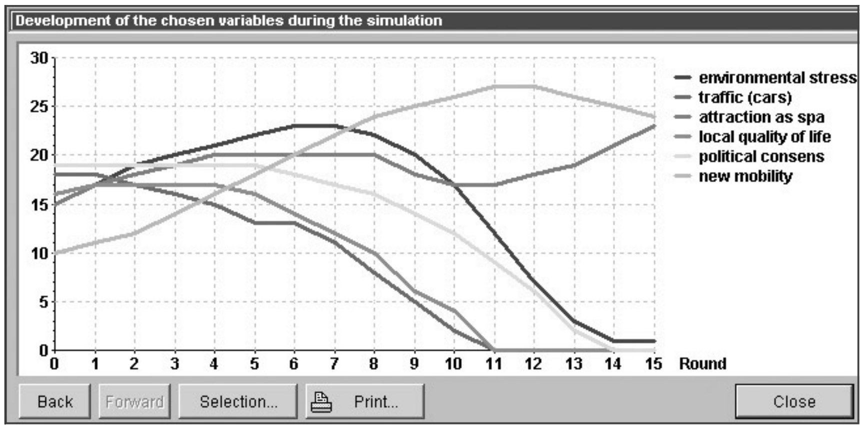


fig. 67: **Simulation scenario** (Oberstdorf system model)

Interactive control

The running of the simulation itself is not continuous but takes place round by round, and in it effect flows can be followed visibly on screen and stopped at any time. The simulation can be terminated at any point, and even the positions of specific variables can in principle (so to speak, as the system as a whole reacting to events) be changed at any time. If an interim balance is required, the simulation can be resumed from the moment when it had been halted, or alternatively after specific interventions have been made. Once the simulation has been concluded it is possible, for instance, to change only the starting-values of specific variables before running a fresh simulation, while the remainder of the program that has been fed in stays the same. Likewise, the sequence of events or even the design of effect curves can also be changed while the rest of the input remains unchanged. The range of possible policy tests is thus unlimited.
In the wake of a simulation the change in the variables can once again be reconstructed step by step in the form of differently coloured curves. The corresponding tableau also records what has changed, when it changed, and where in the course of the simulation the change occurred.
The two simulation runs in our example (figs. 68a and 68b) point clearly to a threshold in the 'consensus' variable that, as can be seen, lies within an extremely narrow range. The relevant message of the simulation for local politics is in this case that, for sustainable implementation of the traffic-calming plans prior to the execution of further measures, a relatively high degree of consensus among the various groups involved is essential. Even then events show that a period of frustration must be expected, with a temporary drop in quality of life (dissatisfaction of townspeople) and in consensus (attacks and disturbances). Here it is a question of holding on until the measures, which will at first lead to an increase in noise pollution and exhaust emissions, have brought about an improvement. The strategic pointer emerging from this is: best to wait a while before introducing further measures and to involve retailers, mountain-railway operators, and hoteliers in consultations with the object of enhancing consensus and receiving sufficient support from all sides in order that others will help with the problems of such a





figs. 68a and 68b: **Development of selected variables during simulation** (Oberstdorf system model). In the top graph 'political consentsus' starts at a value of 17, while in the lower one it starts at 19.

change. If on the other hand the measures are introduced without the relevant local interest groups being in agreement in their regard, the likelihood is that sooner or later they will have to be withdrawn and the whole project is doomed to failure. This effect is more than familiar from many localities where it has not proved possible to retain half-hearted traffic measures over the long term.

Transparent 'what-if' forecasts

In this way our simulations result in genuine 'what-if' forecasts. Their prerequisites can be called up in clear, they remain transparent to all even during processing, and while the simulation is still going on they allow the user to react to the events being simulated. Simulation in the Sensitivity Model therefore performs quite different tasks than is the case with (for instance) the 'system dynamics' models of Jay W. Forrester, where the whole system runs as a kind of closed 'machine' in order (for example, on the basis of specific starting-values) to predict the next 50 years. Here it is much more a matter of giving a light touch to the dynamics of the system, running the simulation in order to test how the system will behave under various 'what-if'conditions, and in the process, while it is running, monitoring developments and on the basis of such monitoring simulating corrective interventions.

With the Sensitivity Model, however, simulation is only one of nine largely independent procedural tools, which means that any errors that may occur in evaluating the simulation will show up in the other tools. So simulation should be seen not as any kind of'topping out' but simply as complementing the other tools of a Sensitivity Model.

Part 4
The new way to sustainable strategies

Introduction

We have seen that interventions in a complex system very rarely find expression in a direct cause-and-effect relation between adjacent elements. It follows that, because of that complexity, traditional linear-causal estimates of the effects of an intervention can only ever be correct by chance; a reliable forecast would be possible only if every individual interaction were captured in full – and then only in a closed system. However, since total data capture will always remain a Utopian ideal, and since in addition all real systems are open and dynamic, models of this kind are fundamentally incapable of predicting how systems are going to behave in future. In other words, deterministic models arrived at on this basis are never wholly accurate, and strategies taking their cue from such models are at best short-term; they can never bring lasting success, as indeed the plethora of failed plans and attempted forecasts of recent decades amply demonstrate.

Having presented the various ways of capturing and interpreting complex systems on the basis of the sensitivity approach, I propose to devote the fourth part of this book to the special solution strategies that such an approach offers, based on certain methodological peculiarities. The resultant qualities as regards holding an efficient dialogue will help the decision-makers involved to reach answers relevant to the system they are dealing with and thus achieve a sustainable consensus even where interests diverge. The particular nature of interactive computer assistance, the holistic representation, and a didactics in line with the modern biology of learning (which is essentially interdisciplinary) make a universal range of application possible. A key element of that teaching method (and hence an effective mediation) is the visualisation of connections. It reduces the usually enormous expenditure of time and energy required for finding a consensus between (often only apparent) conflicts of interest because of which many decision-making processes often extend over decades and many a committee goes round and round in circles. If on the other hand everyone has a clear picture of the interconnections (in an effect structure, say), there is no need for monotonous reiteration of what in any case are the somewhat bald statements of 'opposing parties', who feel they must never stop putting those statements on the table. An entire chapter (chapter 18) is devoted to what system appraisal has to tell us. With or without the rest of the Sensitivity Model toolkit, system appraisal is a controlling agency capable of playing a crucial role in guaranteeing holistic interplay of the elements of a complex system and developing viable strategies. It provides a route along which, of necessity, different answers will be thrown up than could be obtained in a non-interconnected fashion.

17 • Special methodological features and conducting a dialogue

Never mind how good it is, any system analysis will remain stuck in the theoretical so long as it fails to accompany its statements into the field of practical application. The fate of many sound but never implemented expert reports illustrates this plentifully. A series of special features of the System Tools instrumentarium therefore owe their existence purely to the importance to securing practical implementation for the strategies developed. So direct access, plausibility, comprehensibility, and verifiable argumentation play an important part at each stage of the Sensitivity Model's operation. The method of system capture described has shown how demarcating and capturing a system are made easier by a matrix of criteria and how the recurrent modus operandi turns such a method into a permanent working tool; it has also shown how, by 'breeding out' errors, so to speak, step-by-step capture leads to a greater degree of error-tolerance when it comes to developing the system model. Through the medium of actual examples, we have seen how strategic indications arising from allocating roles to variables and simple analysis of regulatory cycles helps to uncover deficits in the system structure and how a transparent simulation can be built up interactively and discussed in workshops. And biocybernetic appraisal is always going on in the background, available as kind of signpost for sustainable strategies. Since in general the special instrumental features of the Sensitivity Model also provide new ways of instrumentalising all dealings with complexity, in this chapter I intend to discuss in greater detail the chief features of a strategy that can be implemented and the didactic considerations underlying it. Many of those features arose in collaboration with licensees of the method and came from suggestions put forward by the user club that has existed since the development phase; in other words, they emerged from the requirements of practical application. The principal sources here are the Frankfurt [Germany] regional association under its chief planner, Alexander von Hesler, the NERIS group in St. Gallen [Switzerland], coordinated by Matthias Haller, and the AREEA planning office headed by Emmerich Friedl in Graz [Austria].

Five pillars of a modus operandi appropriate for systems

I have already explained that (and why) the way in which a Sensitivity Model is constructed is recursive. This means that the model remains open at every stage and can therefore be updated constantly. In addition, as an initial pillar of the process, a special methodology of data-screening and aggregation of actuating variables and their interactions has been developed that allows further work to proceed with a few representative key factors. The result is an approximate but nevertheless full picture, the background to which can be refined at will.
A second pillar of the process is the further development of the 'paper computer' into a cybernetic matrix of influence and, building on that, into a tool with which the different roles that the actuating variables play in the system can be calculated from their position in the mutual play of forces. This step usually leads participants to make the breakthrough as regards a joint constructive system capture.
The third pillar is visualisation of the system's interconnectedness by a simply erected effect structure, which makes the special cybernetics of the system easier to understand – in other words, makes its chains of effect and feedback loops easier to interpret. Interrogating the automatic regulatory-cycle analysis means that, already at this stage, the system's essential control possibilities and hence further risks and opportunities can be recognised. Two-dimensional representation of the effect structure also helps far more than words or tables to preserve the overall view, so it also forms the ideal basis for discussion when a project is presented to the political decision-makers and interested laypeople.
The fourth pillar is a simulation program that, based on fuzzy logic, makes it possible to develop and run strategic alternatives (policy tests), what-if prognoses, or the interconnected effects of measures in a way that is clear even to laypeople. With only a few additional particulars regarding the structure of a partial scenario, the user is able to carry out a simple simulation. For more detailed findings, he or she can then add further information to the simulation at any time.
In addition to capturing and appraising actuating variables and connections, the biocybernetic basic rules discussed in chapter 9 play an equally important role as a fifth pillar at all stages of the operation. Regarding their instrumentalisation, the next chapter will have quite a bit more to say. The aim of the constant 'checking off' of the laws of living systems captured in these basic rules in the course of examining the system (from initial description to final appraisal and the measures to be taken) is not just socio-economic stability but also the use (compatible with the system) of natural resources in a context of sustainable development.
The whole process is characterised by being transparent throughout and by the fact that presentation possibilities of every stage of the operation (computerised and manual) are there in each phase. For many users that made the Sensitivity Model an ideal dialogue tool; because, in connection with complex systems, as prerequisites for a rapid building of consensus interactive presentation and mediation are as important for the formation of strategies that can be implemented as system analysis itself.

Didactic requirements of the biology of learning

Great value was attached to the didactic aspect in connection with planning the toolkit. The idea behind the Sensitivity Model (namely, an interconnected *modus operandi* that anyone could understand) needed suitable software to supplement it. Particularly after I had had personal experience, in connection with our system study for the Rural Workshops Project for Ludwig Schweisfurth AG and in connection with the Ford System Study commissioned by Daniel Goeudevert, of the huge amount of time taken up by a sensitivity analysis carried out manually, in the early 1990s computer assistance began to look indispensable if only for reasons of saving time. However, since no product on the software market met my requirements in terms of a teaching method based on modern learning biology, and since approaches to well-known software firms failed to produce the desired result, in the

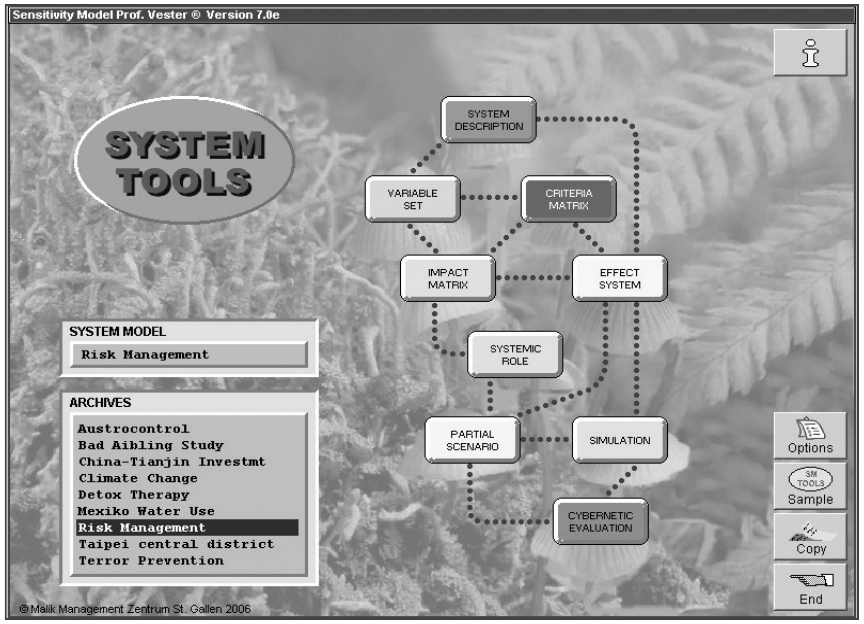


fig. 69: Menu of Sensitivity Model after opening

end all the tools were developed by our own computer technicians, with 'customer' and 'developer' being one and the same.

To give ourselves access to a coherent computer-assisted process that we could use for navigating either through the perception level of the model or through the information level, we had no choice but to develop our own on an empirical basis – which ultimately turned out to be an advantage. This was the only way we could surmount the resistances inherent in existing management software. It has already been pointed out that, so far as biological design is concerned, the relatively young microelectronics industry, while in good shape compared to other technologies, does suffer from the selfsame problem in that its software lags behind its hardware.

Actually, there is no mystery about this gap between ingenious hardware and hidebound software. The fact is, traditional software programs spring directly from linear thinking; they are fixated on processing the largest possible amounts of non-interconnected information. So it is hardly surprising that even ostensibly appropriate software is unsuitable when it comes to dealing with complexity. As everyone knows, the directions for use and the manuals are already disastrous, to say nothing of the usually rebarbative screens and general lack of user-friendliness. As in school, 'classification information' prevails; the entire focus is on pigeon-holing and saving, with many things made not easier but often more difficult than they were without computerisation. For our purposes it was therefore particularly irritating that computers using DOS and Windows are incapable by the very nature of their operating software of furthering an understanding of interconnectedness. On the contrary, they tend to make linear thinking (quite unsuitable, as we have seen, for dealing with systems) more 'efficient' and thus set it in stone.

So the shopping-list that we drew up for the development of a software program that even people who were not computer buffs could use looked like this:

Comfortable user interface

In performing the steps of the operation on the computer the user is supported by a user interface that corresponds to the findings of modern learning biology. The 'menus', that appear on the screen are attractively designed and non-codified and make it possible to work quickly and efficiently without any knowledge of programming; the computer, in other words, can be used directly by the user without having to go through an IT department. Operation is as simple and self-explanatory as possible, so no manual is required. This promotes a directly interactive dialogue, as illustrated by some of the examples from a wide range of users cited in chapter 18.

Permanent orientation

From the 'menu', the user is able to inspect the state of the entire process at any time; that is to say, the person using the software can see which manual or computer-assisted stage of which system model he/she is in at the time, which steps have already been taken, and which step comes next.

Secure user guidance

To guarantee unrestricted entry into each phase of the operation, the user is in principle free when it comes to choosing steps as the process

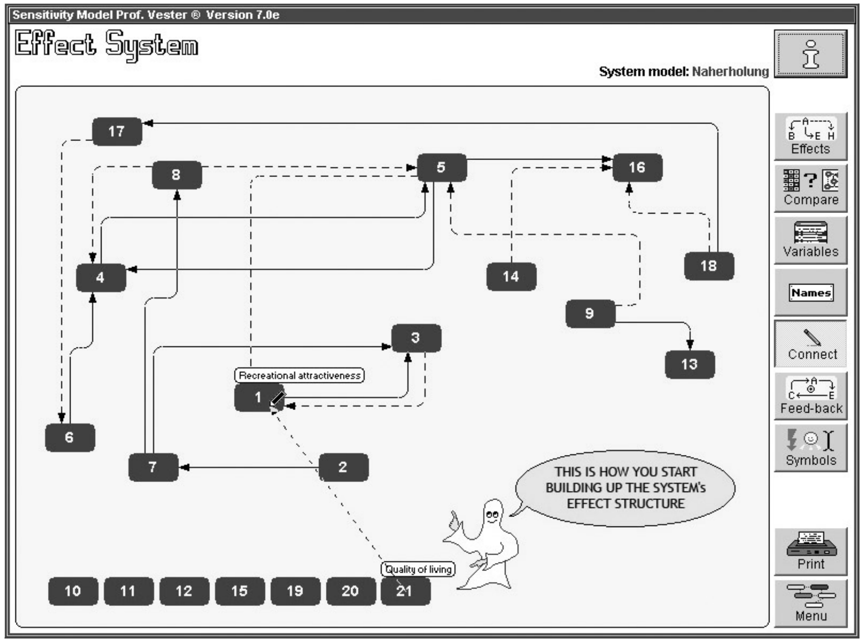


fig. 70: 'System spirit' in connection with building up effect structure

unfolds. However, if the user calls up a step that, in the light of what has gone before, it makes no sense to process (whether because the necessary input data have not yet been generated or because preferring different steps would lead to clearer results), an 'alarm bell' will draw attention to the dangers of the procedure selected.

▶ High tolerance of error and recursiveness

It was also essential to develop a program that does not ask for the data to be re-entered from scratch if the user makes a mistake but remains correctable to the end, thanks to a relational databank. Unlike other analytical tools, therefore, the program has to be extremely tolerant of error. With a recursive modus operandi, representation of the system under investigation can repeatedly, up until completion of the model, be checked against itself – that is to say, through feedback with reality. This, after all, is the only way of guaranteeing the dynamics of the model and a cybernetic procedure.

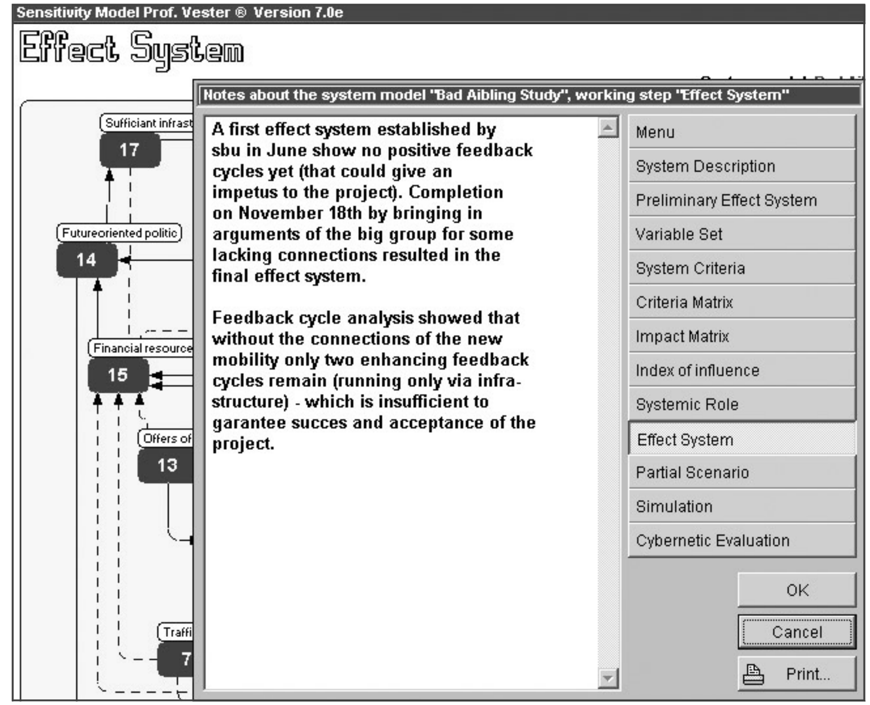


fig. 71: Notebook function of Sensitivity Model

▶ Information aids

Methodological information for the unfolding of the process (e.g. for identifying individual cybernetic characteristics such as diversity, feedback, flow, dependency or for the conclusions of the matrix of criteria, for simulation purposes, for how the matrix of influence works, or for the methods of the interpretation model or the appraisal model) is best obtained through what we call 'learning by doing' – that is to say, in the modelling process itself. Uncomplicated entry is provided by a demo model as continuous specimen example, with the aid of which all the possibilities of the 'toolkit' can be tried out without risk in that all changes made are automatically cancelled on quitting the demo. As a support that can be called up at any time, in the info-window of each step of the operation there is a sequence of images in which a 'system ghost' gives a clear, simple introduction to the individual stages of the process.

▶ Documentation

Ideas, interpretations, recognitions, and remarks resulting from particular thoughts that occur to the user while sitting at the computer can be interactively allocated to the corresponding step of the operation without leaving the menu surface. For this purpose, each step has a 'notebook' attached to it, the contents of which can be called up for each stage of processing, regardless of which stage the user is in at the time.

Meeting this list of requirements in practical terms meant clearing entirely new paths in program design. By independently devising essential tools and a window technique developed specially for the Sensitivity Model, it was possible to reduce the memory and function needs of the toolkit to such an extent that all operations could be run at a satisfactory speed with a fraction of the capacity normally needed. This also meant that any special hardware could be dispensed with (the original DOS program fits on a 3½" MF2HD floppy with 1.44 megabyte capacity and thus in the operating memory of any PC or laptop). Furthermore, an EPROM plug (hardlock) protects the program against unauthorised access and copying, which means that only the authorised user can call it up.

Presentation and reaching consensus

The program structure of computer assistance designed in this way allows planners and those affected to be involved interactively as part of the interconnected system. Consequently, one is never working against but always with the forces present in the system. As has repeatedly been observed in connection with projects executed with the aid of the Sensitivity Model, this strategy is extremely useful as regards the vitally important business of achieving consensus.
In this way interconnected thinking is almost imperceptibly converted into practical application, with comprehensible visualisation of system connections constituting a welcome presentational aid. How this is experienced by users is clear from the following quotations:
In a report from the 'Research, Society, and Technology' division of DaimlerChrysler AG we read, for instance, that in this way working with the Sensitivity Model managed to spark off an integrative communication process as a result of which 'bringing together different opinions, interests, and aspirations received a substantial boost. Interdisciplinary communication within the team is substantially improved, leading to a higher degree of identification with project results. The process of communication amongst experts is meaningfully supported by technology. An extra motivational thrust comes from the system being so easy to operate, giving this contact with technology almost the character of a game.'
A similar view was expressed by Markus Fischer in connection with a system study of domestic architecture: 'The matrix of influence always prompted discussion, in the wake of which participants in the group found themselves speaking a common language that gave them a more precise idea of what others were trying to say with the terms they employed.' And in his dissertation about risk management in medium-sized companies, Rainer Grünig writes: 'Working with the Sensitivity Model triggered intensive processes of group dynamics among the project groups involved.'
This integrating psychological effect when people work together on developing a system model leads to radical curtailment of fruitless debates, largely because of the immediate possibility of articulating views and having those views incorporated in the emerging model. No one feels overlooked or railroaded; everyone finds himself or herself reflected in the system model and his/her views quickly and sensibly accommodated within it. Once it has got going, this way of examining a system usually constitutes an enjoyable experience for everyone concerned. Even later on, when it is a question of choosing the first system-relevant solutions and deciding what is to be done, experience shows that frustrations fail to materialise, in large part because it is no longer one individual winning through against all others. Instead, the answer comes from the system; no one is over-ruled. As a side effect, this mediation has a threefold cost advantage: through drastic time-saving during the planning process itself, through the cybernetic strategy adopted for implementation (consensus in logistics), and last but not least as a result of avoiding abortive developments in connection with the system under investigation.

Integration through system representation

Finally, taking one's bearings from the system rather than from areas of expertise or subject divisions has the effect of bringing together those involved in a system, even where they were not communicating previously, by enabling them to see how the system hangs together. As regards a common strategy, this makes them feel: 'We're all in the same boat.'
In connection with an urban-development project in Jena, system-oriented mediation and presentation succeeded, as already mentioned, in steering the dialogue in such a way that for the first time a complex theme could be processed jointly and representatives of different departments who had previously not been in the habit of exchanging information of any kind were able, in conjunction with representatives from industry, traffic, regional planning, and nature conservation, to develop a common model. The city fathers were particularly surprised at the breadth of the consensus that came about regarding interconnected effects, the strengths of actuating variables, and their roles in the system. Here is what Norbert Rippberger of the German-based international planning company Urban System Consult GmbH had to say: 'Because of the possibility of parallel processing and constant updating the members of the study group are able at any time, on the basis of the underlying set of variables, to process their own subject areas, draw up partial scenarios, and try out and evaluate their interventions and control opportunities.'*
Crucial as regarded bringing together those involved in the system were in this and many other cases computer-assisted presentations to participants. These make it possible, right from the outset, to include interactively both decision-makers and those affected by their decisions as part of the interconnected system and to add their contribution to the databank, with the result that the strategy that eventually emerges is supported by a broad majority.
As regards publicising this mediation process, it is extremely helpful that even the current state of individual steps of the operation can at any time be brought to the attention of persons standing outside it. Once a system model has been developed, it enables external observers and advisers quickly to spot (say) the key factors of an operation and to learn the language specific to that business. At least partly because the functions needing to be performed in order to build up an effect structure or a simulation are not codified at a background level but are fully visible on the screen and can be followed, the Sensitivity Model basically offers a new type of knowledge management.

Tools independent of topics

One instrumental peculiarity of the system approach that should not be under-rated is that its 'toolbox' is wholly topic-neutral. The Sensitivity Model can be used almost universally without changing the manner of its application, the contents and layout of its desktops, or the bases of assessment of its tools. The simple reason for this is that the procedure relies on the basic phenomena of complex systems, which are always the same, regardless of the magnitude and nature of the problem being investigated. The examples assembled in chapter 19 will illustrate this further.

* Under the headline 'Narrow thinking thrown overboard', one Jena newspaper noted in its coverage of 'Sensitivity model for Jena's urban planning': 'It could be that future decisions in our city will be taken more and more on the back of holistic thinking. The 'blame' for this lies with a research project that the Frankfurt firm of Aufbau AG and our city have been pursuing for a year and have now pulled together in a final report. At the heart of the project is the Sensitivity Model, a now computer-assisted procedural model for interconnecting thinking and planning that has been applied to Jena as a simulator for urban-planning purposes.'

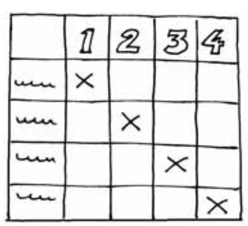
Here, in summary, is another look at the principal features of the procedure:

Holistic capture

As regards enabling the user to capture a complex system together with its socio-economic-ecological environment as a biocybernetic whole, ordinary software programs are no good because of the way they fail to structure the vast amount of data available. Only tools developed specifically for the purpose to select variables and bring about a drastic but systemically relevant reduction of data make the business of capturing and assessing complex systems a practical proposition.

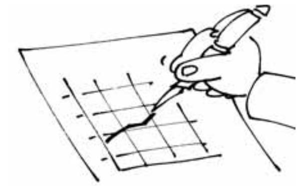
No more floods of data

Instead of drowning the user in data, as usually happens in connection with attempts to capture complexity, the Sensitivity Model makes do with a manageable number of representative actuating variables thanks to a programmed screening process designed to restrict the variables to be taken into account to the minimum. At the same time this solves another problem: as well as quantitative inputs, qualitative connections are also able to enter the equation, where they can be processed alongside the former.



Fuzzy logic as foundation

By using a mode of display related to the Petri net and by applying the mathematics of fuzzy logic, the Sensitivity Model is able to draw connections between data of lesser relevance and through them reach conclusions about how the system under investigation functions. The background here is the concept of viability through self-regulation and flexibility, best assured by optimum observance of the basic rules of biocybernetics.



Interactive operation

The Sensitivity Model toolkit incorporates new visualisation aids and largely verbal rather than codified statements with the deliberate intention of facilitating interactive use; the user will find him- or herself in a constantly open dialogue between the computerised and manual parts of the proceeding.

Permanent working tool

Since that dialogue takes place at all stages of proceeding and even reaches into the interactive unfolding of the universally transparent simulations and policy tests, it also permits the kind of recursive working method that is so important in connection with complex systems. Consequently, every step along the way remains open right up until the end; it is permanently capable of being updated, with the result that even 'finished' system models are always available for further working at a later date.

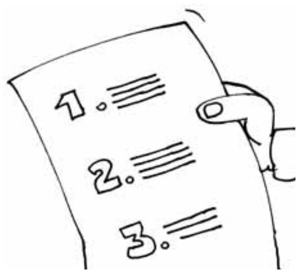
Argumentation aid

On the basis of rendering connections visible, didactically innovative methods of simulation, interpretation, and appraisal provide useful political and material aids to decision-making for the future development of a system. At the same time the model also furnishes the clear arguments that are called for here and without which a person having responsibility for decision-making cannot operate. Manipulation (for instance, by influencing the way the system is captured) is in no one's interest because of the way the consequences are not directly foreseeable – indeed, may well be counter-intuitive.

New kinds of solution

The behaviour of the system will always be interpreted in the light of its 'sensitivity' or robustness within the system as a whole. Under the chief criterion of 'enhanced viability' there are new kinds of potential solution and fresh opportunities available that spring not from the user's wishful thinking but from a better understanding of the system itself.

More scope for action



The biocybernetic view of things also does not supply a formula that can be applied in a rigidly universal manner. It offers no standard solution but one that will vary from system to system, often coming up with a whole swathe of sometimes surprising alternatives. As a result, scope for action is not restricted to a single fixed goal but will be greatly expanded – while still leaving freedom of decision unimpaired.

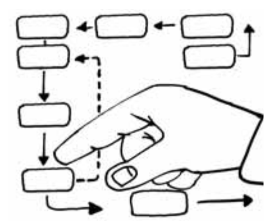
An end to forecasts that make no sense

The outcome of Sensitivity Model investigations consists not in the usual types of prognosis. The Sensitivity Model shrinks from developing future scenarios or predicting what is going to happen; where complex systems are concerned, such predictions are in any case obsolete. Instead, it will help the user to recognise the qualities and development potential of such a system and, using 'what-if' forecasts about how the system will behave, treat those equalities and that potential in such a way that the system can cope better, even with unexpected events.

Thinking aid, not substitute for thinking

In other words, a Sensitivity Model does not remove the necessity for decisions. It is an aid to thinking, not a machine for doing it or a substitute for it. The user's own intellectual efforts are still required. However, they will be made noticeably easier in that all mechanical, organising, and documenting activities are so automated as to bring the cybernetics of the system to the fore, enabling the user to trace what we call the 'parallel processing' of things going on at several levels simultaneously, which no one can do in his or her head.

Back-up for interconnected thinking



Beyond that, the instrumental framework of the Sensitivity Model and the constant presence of the system as a whole create a supportive context in which, particularly in groups and workshops, 'interconnected thinking' will come to 'permeate' everything and there can be no relapsing into linear thinking with its fruitless, time-consuming debates (something difficult to avoid without the right instrumental support). However, even the usual scenario technique, which connects up any old partial aspects into scenarios without regard to systemic relevance, says nothing about how the system can be expected to behave. Only the Sensitivity Model as a whole also provides the necessary back-up as to what links should be drawn and how this should be done.

18 • Strategies and measures for system evaluation

System evaluation as accompanying tool

A continuous controlling agency in connection with the sensitivity procedure is biocybernetic 'system evaluation', using the eight basic rules set out in chapter 9. It accompanies the whole process of model construction, all the way from system description to simulations, and is almost exclusively performed by hand. In this connection the computer only provides structured documentation, though for the purposes of targeted discussion and presentation this is a great help. The necessary information is recruited from virtually every stage of the operation and can be fed into the 'system evaluation' tool (structured in accordance with the eight basic rules) while the model is being developed. The dialogue thus enabled is particularly constructive and consensus-building, since it means that the step from analysis to decision-making can be undertaken jointly.

Basically, system evaluation serves to examine the characterisation of the system under investigation on the analogy of the criteria of an intact ecosystem; it further serves to deduce suitable strategies and measures for dealing appropriately with the system. The orientation model based on the diagnosis-therapy pattern outlined in chapter 10 thus becomes instrumentalised, with the result that the comparative 'system-viability test' evolves into a 'system therapy'.

The process is made easier by the fact that evaluation in accordance with the eight basic rules can be carried out not only with the system as a whole but also with individual parts of the system (on the basis of the partial scenarios) as well as every single one of the seven areas of life.

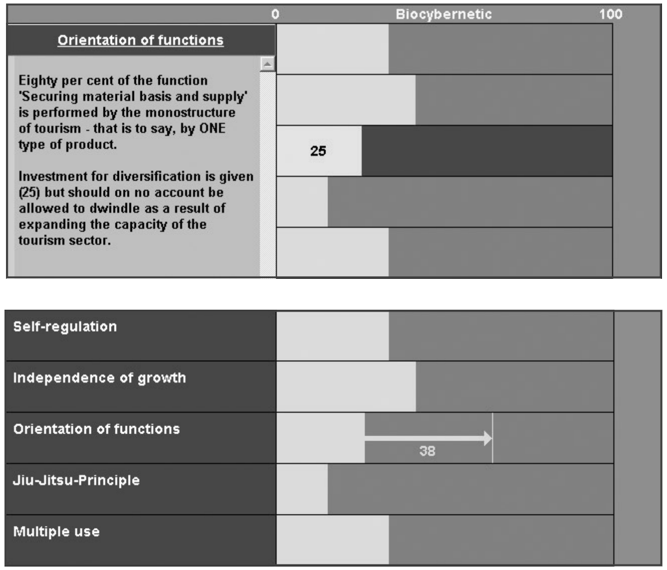
Partial evaluations of individual areas of life within the system are also thoroughly justified with a view to an overall assertion, because of course the peculiar thing about complex systems is that enhanced viability in sub-systems also enhances the viability of the system as a whole

– and vice versa. In this way different scales of evaluation (of two areas of life, say) can be compared in order to see with which rule and at what point in that rule there is a particular shortcoming. Similarly, the overall scale of a system model may be compared with that of another, or the starting condition of a system may be compared with what on the basis of the proposed strategy can be expected to be its new state, and the position on the scale can be read off to determine whether and at what point there really has been an improvement in system cybernetics.

In connection with that 'position on the scale', this is not at all about absolute values such as might be argued over at length; ultimately it is about relative 'before/after' comparisons. In other words, it is a question of whether, in consequence of an intervention or change, the scale shifts to the left (technocratic) or to the right (cybernetic). The tool then offers the possibility of backgrounding the first scale and bringing up a second scale to reveal what has changed in the mean time. In this way, the specific differences in the fulfilment of each of the eight basic rules are sharply brought out and the starting-points for successful treatment documented visually.

Accordingly, a development in the direction of greater viability can always be gauged from the extent to which the system increasingly makes the biocybernetic basic rules its own, acquiring greater robustness vis-à-vis external disturbances. One might characterise the process by saying that the system gains in 'cybernetic maturity'. The conditions of stability of a 'mature' system consist on the one hand of its being in a position to maintain several part-objectives simultaneously (i.e. without these conflicting with one another) in a stable condition (multistable system) and on the other hand of its having several operational alternatives for the regulatory cycles within its complex effect structure (ultra-stable system).

It follows that 'cybernetic maturity' is the same thing as multi- or ultra stability. However, in no case should a mature state be regarded as the end-point of a development; the fact is, experience shows that a certain fluctuation within the overall evolution of a system (with occasional transitional states of lesser maturity) undoubtedly plays a role in eventually achieving long-term viability. Seen against a larger time-horizon, such fluctuations might be seen simply as regulatory processes of super-



figs. 72a and 72b: **An example from our 'new mobility'** study shows two small excerpts from the partial assessment process for the 'Economy' area, with fig. 72a showing the initial situation and fig. 72b the situation following the (hypothetical) introduction of specific measures, both in regard to the third basic rule – namely, orientation by function.

ordinate feedback control systems. For human institutions (companies, towns and cities, countries), viability thus means that they remain both capable of action and capable of being controlled and developing.

System structure and fuzzy logic

With the possibility of biocybernetic system evaluation the use of fuzzy logic in the area of decision-making also receives a fresh basis. The main reason why the inherently very promising help of fuzzy logic in depicting 'rough but right' system models has been little used hitherto is that the kind of pattern-recognition (an analogous process, after all) that it makes possible can only be translated into practice if corresponding comparative structures enable 'resonance' with that pattern to take

place. For instance, even in the fuzzy computer portrait of Abraham Lincoln (see fig. 5) we should never be able to discern the face unless a kind of 'facial archetype' was already lodged in our brain by which recognition of the pattern of squares might take its bearings. In the study of complex systems the organisational structure of living systems (i.e. the biocybernetic 'orientation model') acts as such an archetype, beginning to resonate with the system under investigation as a result of the eight basic rules being 'checked through'.
As soon as we employ that organisational structure as a controlling tool for forming analogies, suddenly all the possibilities that fuzzy logic offers us in terms of performing a sensitivity analysis become workable and usable. On the other hand, arbitrary comparative models arising out of constructed patterns or patterns derived from ideologies furnish no tried and tested orientation model for the objective of 'increasing the viability of a system'.

Organisational bionics as connecting thread

Even without the rest of the Sensitivity Model tools the principles of biocybernetics have their own independent significance as regards a 'rough' decision-making process. Practical examples show that simply going by the checklist of eight basic rules given in chapter 9 can offer certain guarantees that innovative system-compatible strategies will be developed and implemented. Since these basic rules combine economics and ecology, they have already found their way into technological developments, architecture, urban planning, security policy, educational principles, and management strategies. Here are a few practical examples that will make this clear.
As already mentioned, by applying the eight basic rules a key security instrument of modern management (the familiar tool of 'controlling') has widened into a whole toolkit known as 'biocybernetic controlling', which uses the steering rules of living nature as its touchstone. This development was dictated by the need to preserve the habitat that supports us all and to make it the standard of all controlling, thus preventing companies from sawing off the branch they are sitting on. The man

who initiated it is Cologne management economist and publisher of Controller Magazin Elmar Mayer, who showed that consistent application of the eight basic rules will avoid much misdirected investment, over-capacity, and production inappropriate to the market. Similar successes have been achieved with cybernetic architectural planning, one example being Heinz Grote's K.O.P.F. system (discussed in chapter 3), where a combination of self-regulation, functional orientation, the ju-jitsu principle, and multiple use generates a form of organisation that saves both time and money.

Even in connection with a purely technological development, management consultant Gerd Brüggemann took the basic rules that it implemented and used them as his marketing strategy for the introduction of the VIBCOS system 'to control vibration and noise'. In the VIBCOS system, by practising self-regulation in accordance with the ju-jitsu principle, the vibration of heavy grinding, polishing, and milling machines is combated not externally, using very expensive protection equipment, but by having it absorbed by a simple coiled-spring regulator installed beneath the machine bed and fed back into the machine, which then 'destroys' it, so to speak. Noise is markedly reduced and the machine works with greater precision, needing only very occasional relevelling. As a result, with a tiny expenditure of energy machine availability is increased and damage to buildings minimised.

To similarly good effect the same Brüggemann, working in association with Wolfgang Guth, developed a new rental concept for Augsburg's Gewerbehof industrial development, and by applying the principles of symbiosis, recycling, and ju-jitsu contrived to achieve stable use. Rather than relying on a single large tenant, he went for a mixture of small-scale operations. Tenants were selected on the basis that their specific strengths in the areas of infrastructure, energy, and product formed a harmonious whole, and in this way it proved possible, within a mere three months, to let out 90 per cent of the long-vacant complex.

As my final example of how simply using biocybernetics as a signpost can lead to new ideas for solutions appropriate to systems I should like to mention the remarkable concept of a biocybernetic metropolis. In China alone at least 50 cities of over one million inhabitants are going to have to be planned if the uncontrolled (and no longer tolerable) growth of that country's existing urban agglomerations is to be avoided. Aware of this fact, architect Klaus Jahn of Gauting, near Munich, has designed a visionary project on the example of nature, consistently applying the basic rules of system cybernetics and human ecology. The structure of these vast, car-free megalopolises, which like atolls will be made up of smaller units, is planned at every systemic level as a self-creating total organism. In terms of infrastructure, too, they incorporate wholly new urbanistic solutions.

Biocybernetics and spontaneous order

Wherever the eight basic rules are applied, a wealth of powerful interactions form spontaneously and with them a new systemic structure going beyond the matter of immediate concern, a structure with new control possibilities that may not even have been envisaged originally. Here we touch on an interesting phenomenon of which we should make conscious use in our dealings with complexity and which we should keep constantly in view in connection with developing sustainable strategies. The fact is, the deeper meaning of biocybernetic system evaluation is closely associated with a phenomenon that can be observed in nature: the phenomenon of the 'spontaneous generation of order'. Living systems are an example of how, as a result of specific attraction between initially isolated parts and of resonance with ordered patterns, order can spontaneously arise out of disorder without any reduction in entropy – in other words, without the new state being any less probable than before. Biocybernetic evaluation helps us to discover such possibilities of spontaneous order formation, and the strategies developed as a result will contribute towards furthering them. In the process the eight basic rules give information about how the interactions between the components of a system have to be constituted if the system is to be in a position to form order spontaneously and maintain that order unaided.

Even to insert a new 'building block' into a system correctly, three things must be observed:

- its localisation within the other components of the system;
- its connections with the other components of the system;
- control of its effects and repercussions.

The planning and development of a system should ensue from the outset as in the living world, i.e. as far as possible through self-steering links in feedback with the environment, exploiting available forces (rather than putting up resistance to them). This is the surest way of obtaining a cybernetically meaningful structure. 'By forming spontaneous orders, far more complex systems can be achieved than is ever possible through conscious planning and creation,' Friedrich August von Hayek once said in an extremely thought-provoking sentence.

Which brings us to what is perhaps the most significant problem of the whole systemic approach: namely, how it relates to the laws of entropy of the thermodynamics of irreversible processes in open systems. As we know, those laws say that entropy is a measure of a system's state of order and that this always strives spontaneously towards a more probable, i.e. more disordered state. This is so obviously contradicted by the formation of spontaneous ordered states in living systems that over time more and more auxiliary constructions have been adduced to rescue the general validity of this assertion – the notion, for instance, that an open system can spontaneously heighten its order (leading to a corresponding decrease in entropy) on one condition: namely, that the state of order in the system's environment decreases accordingly and the entropy there increases. However, this requirement strikes me as more applicable to 'failed' systems.

Having raised certain considerations regarding the structural peculiarities of living systems in my 1980 book 'New frontiers of thinking' [*Neuland des Denkens*], a few years later I received substantial encouragement from the work of information theoretician E. Cervén. To my mind, the most important thing that Cervén said was this: the standard interpretation of the laws of entropy ceases to apply when communication (in the sense of regulated processes of exchange among components) becomes part of the structure of a system; because on that pre-condition it may spontaneously strive towards a higher state of order in exchanges with its environment without (!) diminishing the state of order there.

Certainly, the sorts of weak thermodynamic interaction that underlie Austrian physicist Ludwig Boltzmann's concept of entropy cannot account for the existence of living systems. They are founded instead on powerful cognitive interactions between a limited number of different elements with individual properties. Cervén is quite consistent when he writes: 'Such processes seek to occur not only in real living systems as an organism, for instance, but also in such abstract systems as societies, cities, companies.' No doubt that is also why organised systems behave differently from the way a knowledge of non-systems would lead one to expect. The fact is, they belong to two worlds simultaneously: because of their individuality they belong to the acausal world, where the laws of statistics do not yet apply, and because of the large numbers of atoms contained in them they belong, with their colligative material properties, to the world of causality. My 'New frontiers of thinking' book discusses this ambiguity at length.

In the case of living systems (a protein molecule building up on the genes, say, or an organism arising out of the nucleus, or an emergent biotope comprising a large number of species), because of a powerful interaction such as symbiosis and other cybernetic chains of events (briefly, because of highly informatory communicative processes between certain parts), the ordered state is the more likely one. The widespread flaw in reasoning here is that order is basically the same as improbability. People cling to this error partly because most artificially engendered states of order do indeed go hand in hand with a decline in entropy. In this case, of course, by way of compensation for the associated decline in local entropy, the entropy of the environment must increase accordingly (and the environment, accordingly, must tend further towards chaos). In all these instances, however, one is dealing with systems in which no specific communication can be synthesised between components, so no powerful (cognitive) interactions can be, either. ('Cognitive' should here be understood in terms of a selective recognition.)

On the other hand, precisely because of the lack of systemic connections and the absence of powerful interactions in a machine, any shortcoming can be eliminated at the source of error itself, without undesirable repercussions arising as a result. In living systems, though, that is just what does not occur – precisely because such systemic interconnectedness and interaction are in fact present. Here, as long as the overall situation is not right, one repair usually leads to another. Even a corpse, for example, is not like a machine that has ceased to work but a complex system quite as open as before, inside which a series of physical and chemical processes is taking place. The only thing is, these are quite different processes than were going on prior to the extinction of intercellular communication. With death, the system switches from biological to non-biological thermodynamics, chemical processes abruptly change direction, processes of decay and decomposition take place, and from that moment the laws of entropy that Boltzmann derived from the thermodynamics of Rudolf Clausius (ultimately from the way a steam-engine works), as they apply to irreversible processes of statistical mechanics, once again become fully applicable.

The second law of thermodynamics therefore holds good only for statistical systems, between the components of which such interactions do not exist (and where – this also follows logically – there is no reason for them spontaneously to organise themselves into a higher order). However, the laws of entropy are often interpreted to the effect that any formation of order and hence of life must in principle be associated with a decline (requiring a constant input of energy) in entropy (known as 'neg-entropy'). Yet precisely this contradicts the original definition of the laws of entropy as applying only to statistical processes.

Pattern of organisation as connecting thread

It is thus a question, if viable systems are to be made possible, of finding out what must be combined with what and how for the resultant combination to be able spontaneously and at not too great a cost (also, without needing to destroy the orders outside the system) to fall in line with a higher order. To track down the secret of the spontaneous formation of order, one obvious approach was again to hold on to the only unwavering instance – namely, intact ecosystems and thus life itself and its successful forms of organisation. It was in analogy to this that the checklist of eight basic rules came about, which is why we should try if we can to transfer those rules to systems we create ourselves.

What will probably emerge from this is that we can confidently follow this model not only from the ecological and economic points of view (the directives of the EU's eco-management and audit scheme, the EMAS recommendations, might be seen as a small step in this direction) but also, curious though it may sound, in regard to our understanding of democracy. The fact is, biocybernetics (which governs the management of viable systems) is so constituted that the resounding success of biological life is not in any way based on dirigiste measures but on a clever combination of self-regulation and control, albeit one that never oversteps the bounds of a cybernetic framework, a framework that entirely spontaneously lays down strict limits while at the same time giving the system its chance of evolving.

Beyond this, following the basic rules helps us to find ways in which a system (or new structure of a system) is not 'made' at great expense (constructivist management) but emerges spontaneously at little expense (evolutionary management). For this reason, it is important that even at the planning stage one should focus not on a specific state of affairs or on seeking to predict this but instead on striving for certain capabilities and on looking for opportunities to develop them.

Even the mere availability of certain basic components can obviously lead to spontaneous organisation – and not in any random 'statistical' manner, as suggested by most eco-physicists and by the thermodynamicist Ilja Prigogine, but under the control of the emergent system itself. German theoretical physicist Hermann Haken describes this in his 1984 book *Synergetik: Lehre vom Zusammenwirken* [this and a sequel were published in an English translation, *Synergetics: Introduction and Advanced Topics* , in 2004] as follows: 'In an open system the individual components are continually testing new attitudes to one another, new kinds of motion process, or new kinds of reaction process, in each of which a great many parts of the system are involved.' He goes on to say that the patterns to which this gives rise impose a macroscopic structure on the system that appears to us to be of a higher order. In the case of living systems that develop such structures as they grow (i.e. not like a machine assembled from parts), hereditary dispositions and environment interact in such a way that, while fixed order structures do in factoccur, at the same time a sustained dynamic equilibrium of flow prevails.

Energy management appropriate to systems

A widely held false interpretation of the concept of 'entropy' appears to have given rise to a need to compensate for the creation of order in our technosphere by means of increased disorder in the biosphere that supports it, together with an additional energy-input. As explained above, however, the probability that a 'set' (often by the simple addition of a part missing from the puzzle) will spontaneously generate an ordered structure is greater than that the disordered situation will persist – and for that absolutely no additional energy is required.

In other words, the sole reason why our contemporary industrial process is self-destructive is that it is anti-evolutionary and is building a technosphere on top of a disintegrating biosphere. The process does indeed seem to vindicate all those who abide by the classic explanation of the second law of thermodynamics, according to which the so-called diminution of entropy (order) in our industrial sub-system is accompanied by a proportionally greater increase in entropy (chaos) in the environment, the only trouble being that in this instance the increase in entropy means the gradual destruction of the biosphere, which gives the fact of having been right all the time an extremely bitter aftertaste. Increasing internal order without destroying external order would indeed contradict the dogmatic interpretation of the second law – although nature demonstrated this millions of year ago, so it must be possible. However, since what may not be cannot be, no one (rather alarmingly) is even looking for another possibility.

Yet the radical rethink that is necessary in this regard (if the biosphere, the only real, permanent basis of our prosperity, is not to be surrendered to destruction) will not aggravate our own energy problems; it will make them easier. The fact is, as soon as we cease to separate energy supply from the development of other social areas (private transport, consumption, living, quality of life, and so on) and see it instead as an organisational parameter in a feedback control cycle with other areas of our environment and our lives but also with regional thinking and local socio-economic locational conditions, the system structure will automatically spawn a wealth of small-scale cooperative solutions and profitable symbioses that might never even have occurred to us, focused as we are on individual solutions. For instance, it is entirely likely that, if we give up our energy dreams based on large-scale technologies, new complex solutions will become possible and necessary, and these could well give rise to a huge wave of innovation.

However, if energy alternatives are under discussion and experts from the various camps are listening in, one gains the impression that they are interested not in achieving an overall energy system but usually only in comparing and contrasting coal, oil, hydro-electric, nuclear, solar, or photovoltaic solutions – all on a massive scale. Hardly any of them speak of reducing energy consumption, cutting waste, low-energy process technologies such as catalysis (rather than electrolysis), energy exchange and recovery, coupling arrangements and multiple use, or (in keeping with the basic rule regarding orientation by function) quite simply of meeting the same requirements by non-energy-consuming means. One of these is satisfying the need for recreation without having to leap into the car or jump on an aeroplane, possibly by making staying at home more attractive than travelling (today's traffic, which can lead to complete gridlock, is in fact increasingly producing this result itself).

As in connection with our comments on the climate problem, this brings us back to human behaviour as lever of change. In the energy sphere, too, the first step in the holistic direction is to concentrate not on consumption, not on supplying ourselves with increasing quantities of additional energy, but on how we can get by better with what we have (a way of thinking that brings us back to the basic rules of recycling and ju-jitsu). The fact is, probably the greatest and largely unexploited source of energy is that of more efficient energy consumption, and the cheapest energy is still energy that is not consumed at all. However, if you look at official calculations and energy scenarios, they take current levels of consumption as a fundamental given, much as traffic forecasts take traffic needs as a given, going on to investigate on that basis how demand is to be met rather than asking how it comes about. Yet this would be a question well worth putting, as the following example shows.

Energy calculations by the Harvard Business School based on comparing a large number of process changes carried out in practice show on balance that, if our present economic habits are to continue, the investment required to create a mere 2 per cent of additional energy would be of the same order of magnitude as would suffice to acquire 40 per cent of useful energy through energy-saving measures. (That is something like six times what nuclear energy currently contributes to the sum total of energy available.) Yet the savings made would not impair our comfort in the slightest. Basically, such a strategy would simply represent a combination of three basic rules: the ju-jitsu principle, multiple use, and recycling. In other words, everything indicates that, as regards the survival of the human species, our way of life and our economy demand a radically innovative upheaval, notably in terms of energy efficiency. Without that upheaval, our present way of going about things will probably induce a global decline in prosperity – for the simple reason that further growth of the technosphere in its current uncybernetic and hence unsystematic form will inevitably bring with it a corresponding disintegration of the biosphere. The question is: do we truly, with our mindless appetite for energy, want to take that risk, knowing that in the final analysis intact ecosystems represent the only real, long-lasting basis for our future well-being?

19 • A universal approach to planning

A holistic representation of any kind of complex system (any kind whatsoever) must be based on a model procedure that is topic-neutral, on a hypothesis that is not attached to particular disciplines, subjects, problem areas, or interests. After all, the reality to be represented in this way is neither subject-oriented nor split up into categories. The broad spectrum of examples of the application of the Sensitivity Model and its tools that we have sketched up to now has already reflected this overarching neutrality of the systemic approach – an approach that removes the problem of including factors that, while having nothing to do with the particular subject concerned, are of decisive importance as regards the system to be investigated (a notorious handicap in connection with planning procedures structured in a subject-specific fashion). Only this non-specific orientation of the toolkit as a whole will ensure holistic capture and interpretation of the system it is used to study. It is the most important foundation for any sustainable strategy.

Two authoritative voices, one from politics, the other from the corporate sphere, encouraged me in the early 1980s to make what had previously been a somewhat 'hand-knitted' process more widely accessible by developing a computer-assisted instrumentarium or toolkit for general use and to start designing an appropriate software program. One of the voices was that of Minister Goerke, chairman of the German national committee of UNESCO's MAB programme (*Man and the Biosphere*), who in his Foreword to our first (1980) system study expressed the following hope:

> "It is my opinion that with the Sensitivity Model presented here an essential contribution can be made towards improving planning decisions in industrialised and in developing countries. With the aid of the instrumentarium put forward here abortive developments can gradually and purposefully be eliminated and more easily avoided in connection with fresh developments

> in future. The Sensitivity Model is based on an understanding of ecology that is far from content with protecting individual parts of our habitat. Instead it seeks to involve all the activities and needs of man and the environment in its considerations, and on the basis of a recognition of connections it tries to harmonise our living-space. The background to all this is the concept of viability through self-regulation and flexibility, for which the best guarantee is the greatest possible degree of observance of the basic rules of biocybernetics"

The second commentary confirming that I was working along the right lines came from Martin F. Wolters, who at the time headed Siemens' 'Artificial Intelligence' division; Wolters discussed the principle and possibilities of the approach I aspired to in his book 'The Fifth Generation: The key to affluence through robots and intelligent computers' (*Die fünfte Generation – Der Schlüssel zum Wohlstand durch Roboter und intelligente Computer*; 1984):

> 'Most complex problems can be solved only with the aid of symbol-processing and artificial intelligence. The planning technologies required for this include one that is especially important and that leads into the field of biocybernetics: the Sensitivity Model. This system of representation, akin to Petri nets, has long since moved on from the experimental stage. It turns out that even small networks of this kind can very representatively supply values corresponding to reality. As a result it becomes possible to extract from just a few relevant data conclusions regarding the functioning of a system. Its widespread introduction will have extensive repercussions on our life together and on how we shall set about solving problems in future. In connection with constructing Sensitivity Models that take account of biocybernetic processes, one can expect that the rough structure of the level under consideration will also, automatically, contain the effect factors of a lower level, together with their interactions. Vester calls this the 'implied rough framework'. Nowadays we talk about 'fractals'. [...] Every organisation, every district-council office, every town-planning department, every credit institution, etc. could afford a 3-person team with the necessary expertise and a computer. It would be able to avoid a great many hefty outgoings arising out of major planning errors, endlessly protracted debates about variant schemes, and fruitless discussions with groups having different interests.'

A number of excerpts from a wide range of projects cited at the end of this book will show that this hope has indeed been borne out in practice.

Universal spectrum of application

The areas in which the cybernetic systemic approach can be applied is virtually unlimited, thanks to the open structure of the instrumentarium. It can be brought into use wherever the complexity of the tasks faced is such that the problem can no longer be tackled with traditional methods. Areas processed up to now include:

- corporate strategic planning
- technological assessment
- development-aid projects
- study of economic sectors
- urban and regional planning
- environmental planning and health
- traffic planning and logistics
- assurance and risk management
- banking and financial services
- security policy and conflict analysis
- examinations of system tolerability
- planning-games and training-courses

A full account of the broad spectrum within which the systemic approach can be applied would exceed the confines of this book. So I shall select only a small number of projects and commentaries that give at least some impression of the range of possible applications catered for.

System-oriented corporate management

For the 'Research, society, and technology' division of DaimlerChrysler AG in Berlin, questions of environmental analysis and social research have acquired substantially greater importance in recent years. According to a group operating there with the Sensitivity Model, management too is increasingly becoming aware that the success of its efforts depends upon corporate policy decisions consistently taking their cue from the environment, particularly as regards decisions having long-term strategic implications. The prerequisite, they felt, for system-tolerable actions or reactions was specific knowledge of connections and processes internal to the system concerned and how systems relate to their environment.

This process of rethinking in industry was based on two impulses, they said. In the first place, the interconnection of actuating variables relevant to the success of a company had increased enormously, as indicated by global pressure of competition. Secondly, the tempo of change underlying the key values of the economic system had accelerated to an unprecedented degree. Yesterday's success was no guarantee any more that tomorrow would be similarly successful.

In a commentary on organisational development we read: 'Complexity and insecurity in the environment of companies are mounting all the time. To underpin their long-term future, companies (which are themselves complex socio-technological systems must understand the complex interplay of their reciprocal relations with their environments and act in that context in a way that is tolerable to systems.' Using a concrete example from corporate practice on the subject of 'management', the commentary goes on to indicate the benefits of the systemic approach 'together with the usefulness of computer-assisted model formation, the key component of which is dynamic simulation [...] In this way possibilities of action at the strategic level can effectively be anticipated.'

As regards the planning prerequisites for a sustainable strategy, project leader Michael Steinbrecher stresses:

> "Because of their varied nature and their interconnectedness and dynamism, it is no longer helpful to break problems down into small manageable sub-areas and find the perfect solution for each in turn. The result, often, is solutions that do not ultimately fit together. It is much more a question of enabling or rather securing successful action precisely while taking account of high environmental complexity (structural and dynamic) and non-transparency of structural circumstances. This is where the real challenge for companies lies: In response to external complexity they must develop sufficient complexity of their own to absorb the complexity of the environment and hence the insecurity about decision-making. One such approach that meets this requirement is the systemic approach."

The basic assertion of this approach is that the steersman (in the cybernetic sense) is always part of the system, and this of course is particularly true of management. According to Gustav Gottfreund, finance manager of the Karlsberg Brewery Association [*Brauerei Verbund*] (the head of which, Richard Weber, president of the Saarland Chamber of Industry and Commerce, has been able to record major economic successes by introducing the idea of biocybernetics into his companies), the question of the proper way to manage is no longer 'How do I run a company?' (where in typically authoritarian management style the company is like a tool in the boss's hand). Nor is it any longer (in line with the widely popular cooperative management style) 'How do we run a company?' (where the company is almost a piece of machinery, with one person pulling a lever, another turning a wheel, a third holding on to one bit, and a fourth giving a shove somewhere else). In future, then, the question must no longer be 'How do I run a company?' or 'How do we run a company?' but 'How does the company run *itself*?' In that moment the company ceases to be tool, ceases even to be a machine, but instead becomes a 'living thing'. And the task of the manager becomes more than of a presenter. The manager no longer has to push some things through and hold others back but to make sure that information is flowing in the right direction, that self-regulation and flexibility remain unimpaired, that things are able to happen of their own accord through interaction, and that the company takes its cue not from its products but from its function. These are new and interesting tasks, needing clever steering. What is required, in short, is cybernetic

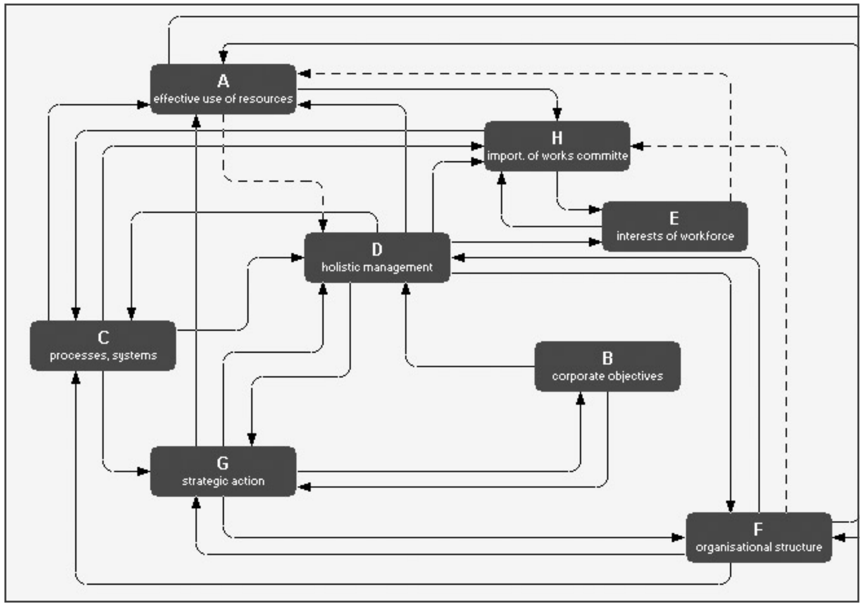


fig. 73: O**rganisational development system model** (excerpt)
On the basis of a summation of variables a network of 30 effect links was constructed. 'Earlier reflections and discussions had already contributed a wealth of new and sometimes very surprising findings, but the increase of knowledge after conducting a simulation of the system's behaviour was once again substantial.'

management of a kind that respects and possibly improves the way the system behaves, aiming its corporate strategy accordingly.

Fractures and upheavals in industrial insurance

On this subject, the following excerpts from a publication by Matthias Haller and Jochen Petin speak for themselves:

> "The fundamental effect connection for a positive development of insurance finds expression in a simple basis effect structure [see the dark boxes in fig. 74]. Building on this, previous considerations can gradually be brought in and supplemented until a sophisticated extended effect structure comes into being using the interconnected-thinking approach.

> The basis effect structure forms the 'motor' in the insurance process. *Extensive identification of risk costs* allows *premiums to be charged at the right level* and leads to a *balanced technical result*. Over time this allows *profitable, growing insurance* to develop. It is the basis for investing in *extended risk management* (RM), which in addition to traditional probability RM implements and further develops the concept of improbability RM. The better this extended RM works, the better will be the resultant *identification of risk costs*; the circle is now closed.
>
> This favourable interplay of variables is not automatically guaranteed. The development may also run in the reverse direction. For example, defective knowledge of risk structures leads to defective identification of risk costs. Premiums are then calculated at too low a level, and insurance losses accumulate. The budget for further development of risk management is further reduced (with a corresponding effect on the future), and so on. In this way (under different conditions) the virtuous circle of the insurance process becomes a vicious circle."

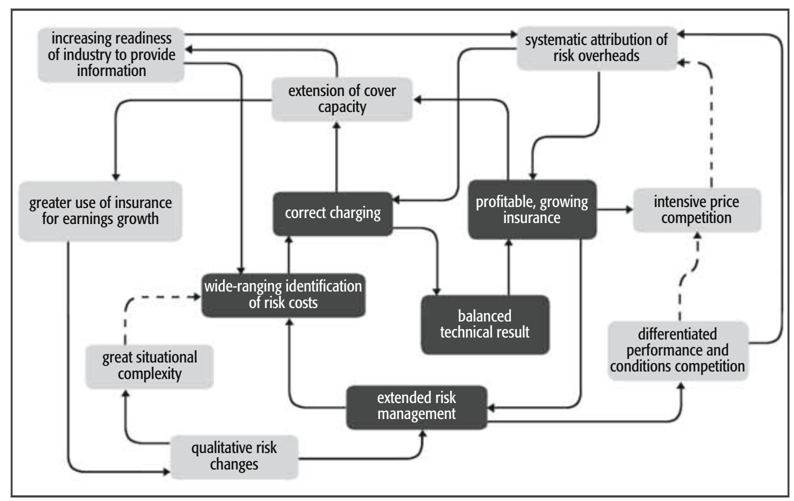


fig. 74: **Industrial-insurance partial model, expanded effect structurea**

The authors' extended effect structure then shows that among the triggering forces for an unfavourable development are *qualitative risk changes*. How big these will be depends very much on how far there is *increased use of insurance for income growth*. One of the crucial prerequisites here is expansion of cover capacity on the part of the insurer. Other decisive factors are *correct pricing of premiums and risk inclination at any one time, which correlates to profitable, growing insurance.*

Risk management in a paper factory

The chief goal of a system investigation carried out by Rainer N. Grünig at the St. Gallen Institute of Insurance 'was to create a deeper understanding of the typical risk problems of medium-sized companies and to examine and optimise risk measures'. The effect structure

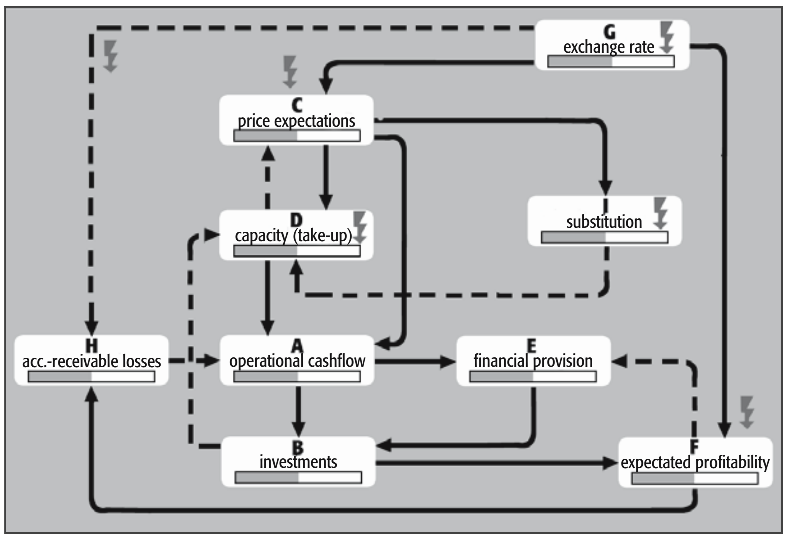


fig. 75: **Simulation of 'Dangers of an economic nature'** partial scenario
Particularly relevant seats of danger are marked with lightning symbols. The bar chart in the box below the name of the variable shows the current state of the variable concerned. The fact that all the bars are in the middle position indicates that at the time of consideration the system is in equilibrium. This means that all processes and functions will operate according to plan and the corresponding expectations will be met.

drawn up in connection with the Nettingdorf Paperworks (fig. 74) shows that the economic system logic essentially remains intact if outside factors do not intervene to slow it down. However, the existence of negative feedback loops is able to buffer the effects both of oversteering and of sudden braking. In various partial scenarios the risks involved here are investigated.

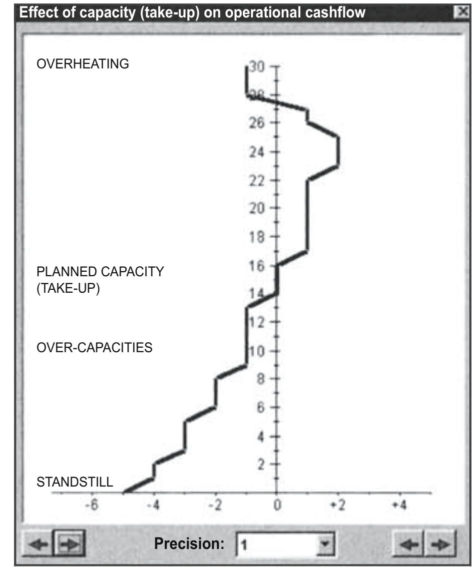


fig. 76: **Paper factory system model, simulation of 'Dangers of an economic nature', effect of 'Capacity used' variable on 'cashflow'**

According to Grünig, the partial scenario 'Dangers of an economic nature', for instance (fig. 75), reveals 'a downturn in the economy and insolvencies caused by payment problems on the part of third parties that led ultimately to accounts-receivable losses'.
Also indicated in the network is 'the special influence of exchange-rate fluctuations and substitution tendencies' on the system. A simulation permits further 'conclusions regarding system cybernetics to be conveyed, which leads to a better understanding of systemic connections, how the system behaves, and the dynamics of variables'. In a digression, the author demonstrates this on the example of the variable 'capacity used' (fig. 76). The state of the variable is defined in four stages. In a state of equilibrium, the variable is located in the centre (planned loading). If loading increases above that point, the result is overheating. Overcapacities exist and product piles up. If loading collapses completely, things grind to a halt.
However, beyond strategic management the Sensitivity Model is also (and increasingly) used in urban and regional planning – from traffic-calming in the Oberallgäu and power supply in Switzerland all the way to China, where for example the system study 'Towards a sustainable city' appeared in 1996.

Ecological planning in China

Carried out in collaboration with the UNESCO programme *Man and the biosphere*, with the People's Republic of China, and with the Federal Republic of Germany and taking the systemic approach as its basis, the *Cooperative Ecological Research Project* (CERP) for the Tianjin region was concluded in 1997 (see fig. 77). In the words of the project document:

> " The complexity of urban systems, the network of relationships between a city of eight million inhabitants and the surrounding rural areas – these things require a fresh understanding. In the past, individual problems were studied and individual solutions sought. It was an approach that turned out to be unusable. Thanks to huge advances in system theory, biocybernetics, and computer science, ecologists and urban planners now have a system-oriented tool that for the first time makes it possible to study such complex systems as the Tianjin conurbation."

fig. 77: **CERP** (Cooperative Ecological Research Project) publication

I had already made clear in 1994, in a Chinese publication edited by Wang Rusong, that our management methods could not set the pattern either for the Third World or for the former Socialist countries. In both cases they had all too frequently promoted disasters, and we had no right to push ourselves forward as teachers. On the other hand, countries such as China had a unique opportunity, using system-oriented planning methods, to launch both modern energy technologies and equally innovative transport systems.
So it was with the help of the Sensitivity Model that the ecological and economic benefits of the proposed plan were simulated and a series of further effect structures worked out, up to and

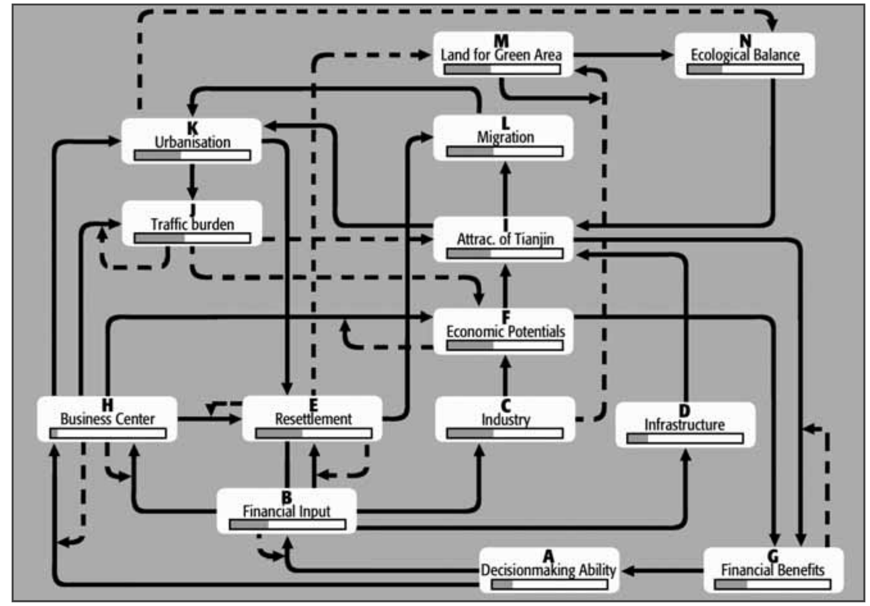


Abb.-78: **Simulation of 'Dangers of an economic nature' partial scenario**
Particularly relevant seats of danger are marked with lightning symbols. The bar chart in the box below the name of the variable shows the current state of the variable concerned. The fact that all the bars are in the middle position indicates that at the time of consideration the system is in equilibrium. This means that all processes and functions will operate according to plan and the corresponding expectations will be met.

including a simulation of the planning process itself and the strategies to be applied. With its significant results and ease of implementation, the project won several prizes in the context of the 'Science and Technology Progress Award' of the Chinese Academy of Sciences.
There emerged a strategic paper whose line of argument, backed by scientists of the Chinese Academy of Sciences in Beijing, represented the first attempt to halt China's ruinously uncontrolled growth, using the example of one urban agglomeration. The first positive thing that struck the operators was that a Sensitivity Model cannot be manipulated in accordance with special interests. So the Chinese planners were also able to have confidence in the corresponding simulation runs. They saw immediately that, if the region was to develop in a sustainable way, there could be no question of drawing in as many financially powerful

investors as possible in order then to end up with similar structures to Shanghai, for instance; instead, they must first establish to what extent their regional system was in danger of collapsing or of rocking more and more violently at an exponential rate, how great was its capacity for self-regulation, how far it interacted with adjacent regions, how flexible it was, how capable of evolving, and what levers could be used to steer it and what could not. Interestingly, simulation of existing plans pointed to a destructive development for the region. This did not change until, in a further simulation run, the direction of a particular effect was reversed, with the result that, as illustrated in fig. 74, 'financial input' (i.e. investors' choice) occurred not before 'decision-making ability', as previously, but only *after* this had established the planning strategy.
In chapter 16 it was pointed out that simulation is only one of nine steps of the operation. But occasionally (as was the case here) it can supply decisive arguments. A similarly revealing role was played by simulations run in connection with the decision about continuing to slaughter cattle in Munich; because simulation programs come in handy above all where complexity calls for a parallel thinking procedure.

Slaughtering large animals in Munich

This project was about the future of Munich's abattoir in the part of the city known as the 'Grossmarktviertel' (Meat- and cenral market district). The question was: should large-animal slaughter, which cost the city more than 4 million DM a year, be continued, wound up, or sold off to a private company in the meat trade?
The *Kommunalreferat* [in Munich, the body responsible for real-estate and commerce] took the view that, particularly in the light of the crisis facing the industry as a whole, investigating the critical issue of slaughtering cattle alone without taking account of the wider environment did not do justice to the problem. Because beyond the particular difficulties of an abattoir (working to full capacity, needing investment, the competitive situation), not only was the wider horizon dominated by headlines about the BSE scare, swine fever, and hormone scandals; the industry was also facing altered consumer sensibilities with regard to

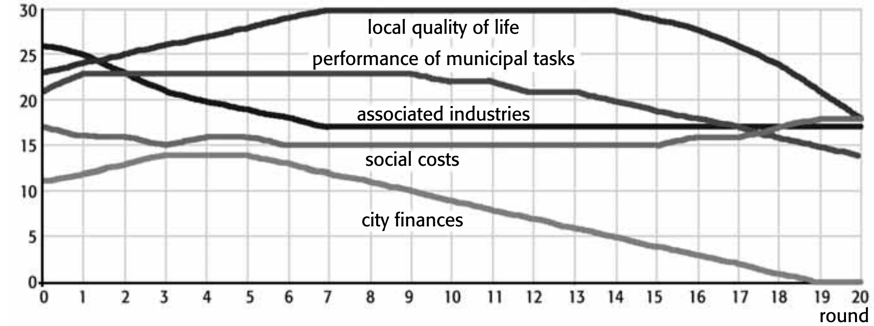


fig. 79a: **Large-animal-slaughter system model**; development of selected variables during simulation of privatisation

large-scale stock rearing, animal transportation, environmental stress, and meat-eating in general.
The future of large-animal slaughter therefore needed to be examined holistically and in an open fashion, looking beyond purely economic factors and taking into account the interests of businesses directly and indirectly concerned as well as of associations and authorities. Only in this way would there be any hope of working out, for the city council, proposals that would suit the system and provide a basis for the kind of decision-making that could expect to find broad acceptance.
Once a system model had been developed in consultation with all interested parties and this had brought home to everyone the interconnectedness of links extending far beyond the abattoir itself, it became clear purely from the effect structures that not only might stopping large-animal slaughter soon mean curtains for the abattoir's other activities and for the adjoining livestock-assembly facility; it might also cut the ground from under the feet of the associated small and medium-sized businesses in the vicinity. In other words, simple closure would probably have landed the council with consequential costs well in excess of the existing subsidy.
Having established this, the next step was to find out by simulation what the consequences of privatisation would be. For the partial scenario in question, several simulations were elaborated (again in consultation) on the basis of various starting-positions.

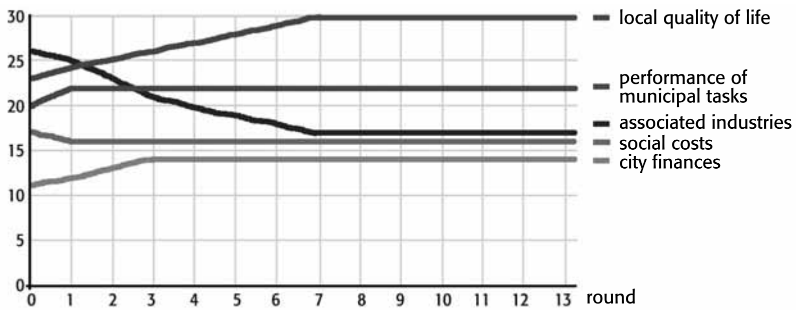


fig. 79a: **Large-animal-slaughter system model**; development of selected variables during simulation of privatisation

As the results of the first simulation showed, while privatisation would mean a short-term gain for the city's finances, in the long term it would constitute a financial disaster. Mounting social costs, loss of quality of life in the district affected, neglect of local businesses as a result of orders coming in from outside, the disappearance of the associated cattle market, and a lack of guarantee of provenance were among many consequences to be feared. Other 'if-then' simulations with alternative possibilities then showed that things would develop differently if the city did in fact sell but in return for an additional guarantee of continued existence imposed certain controls.
In a press release put out by the Kommunalreferat der Landeshauptstadt München its then director, Georg Welsch, wrote:

> What needs to be stressed about this method of examination is the way it not only takes account of the direct effects of possible decisions but also brings in indirect effects, notably the repercussions that will accompany such decisions. Equally important was evaluation of the 'feedback control cycles' thus uncovered, not only from the city's or anyone else's standpoint but arising out of the sum total of the views of all concerned, and these did indeed represent very different and sometimes even contrary interests. Thus group work (particularly the range of aspects, each determined by a specific interest, that this involved) brought a deeper appreciation of the problem and spread knowledge that was of relevance to decision-making amongst everyone involved. […] Findings obtained with the aid of the Sensitivity Model will be able (beyond the project under investigation) to flow into other, future assessments of interconnected circumstances relating to business. So it was possible, on this basis, despite an initially very wide range of interests […] to reach a common view regarding further steps towards solving the problem.

In the mean time it had been possible to sign the relevant contract conferring hereditary development rights on the 'Munich Abattoir Company plc' [Münchner Schlachthof Betrieb GmbH]. The administrative director of the Municipal Abattoir and Stockyard, Roman Brunner, wrote to me afterwards '…that this made it possible to create the contractual basis for preserving the jobs and the whole range of goods and services supply for Munich – as proposed in your report'.

The ecological 'Rural Workshops' project

Also to do with meat-processing was a scheme of a very different kind in connection with which the biocybernetic approach scored another victory against the current craze for the huge and spectacular. In the mid-1980s we were commissioned by the then proprietor of the Herta sausage factories, Karl-Ludwig Schweisfurth, to draw up a concept (since realised) for a new kind of meat-processing company (we came across the systemic image of the concept back in chapter 12). Schweisfurth found that his company (which after all processed more than 300 pigs an hour) had become too big for an ecologically sound supply of meat products such as met his quality requirement to be possible any longer.
In a jointly developed systemic model we showed ways of reducing the enormous outlay that had previously resulted from the sheer size of the company and its monolithic structure. Expensive temporary storage, interim refrigeration, conservation, packaging, and transport had driven a wedge between producer and consumer that brought quality down and drove operating costs up without, in essence, actually having any-

thing to do with the product itself. What emerged was the concept of a new type of small-scale, decentralised 'rural workshops' operating in direct cooperation with farmers and, as a result of a series of cybernetic composite solutions, along lines laid down by the eight basic rules. Following the sale of the Herta business, Schweisfurth implemented the concept in a pioneering fashion with the Hermannsdorf Rural Workshops [Hermannsdorfer Landwerkstätten] and has consistently developed it further – even, because of its ecologically exemplary character, showing it in operation as an official project at the Expo 2000 in Hanover. Here, by way of illustration, are just a few of the parameters that, in connection with this project, arose out of the seventh basic rule ('Symbiosis') and in the course of the gradual build-up of the 'Rural Workshops' did actually come into play:

Parameters realised in Hermannsdorf Rural Workshops project in the light of the basic rule of symbiosis (selection):

- Decentralised production and restricted scale promotes symbioses with surrounding area.
- Combined solutions couple production with waste disposal, e.g. biogas production from organic refuse, dung, and liquid manure.
- Communication between production and customers means mutual support and creative interaction with regard to biological nutrition, environment, and nature conservation.
- Direct distribution and natural methods such as warm-meat processing and guaranteed provenance bring farmers and consumers together.
- Glasshouse combinations facilitate symbiosis of small-animal husbandry, herb garden, recreation, air-conditioning.
- Mutual reinforcement of psycho-biologically responsible livestock raising with environmental redevelopment, waste disposal, improved quality, animal protection, and reduced upkeep and veterinary costs.
- Natural construction methods and greening of buildings promote cybernetic air-conditioning and use of renewable energies. Hence environmental protection coupled with increased profitability.
- Cybernetic production structure. 'Requirements' and 'waste products' of different workshop elements benefit from one another.
- Internal systemic cohesion through cooperation between production, marketing, farm operation, mini-brewery, cheese-making, and other non-meat products.
- External systemic cohesion: social acceptance of workshops promotes product acceptance and conversely. Supply to and exchange of waste products with farmers.
- Decentralised distribution promotes symbiotic advantages through smallness of distribution area. Hence minimisation of transportation, storage, conservation, and packing.
- Alliances with neighbouring producers and service-providers for recycling and energy-use as well as for exchange of personnel.
- Cooperation with municipalities, authorities, and associations leading to a revival of workshop industries, image-reinforcement, and canvassing of public and media.

From looking at environmental tolerability to looking at systemic tolerability

The strategies obtained through the systemic approach seek (usually on the basis of partial scenarios) not only to alter system components and remove variables or (as in the examples of Bad Aibling or the Munich abattoir) to add new ones but also to create new links between them or undo old ones. Simply by doing these things they aim to create a different, possibly more sustainable 'order'. While the first-named strategy (altering the variables involved) is of a more technocratic nature, the second (altering the connections) tends toward the cybernetic in that it corresponds to a change of direction, with the results taking effect only gradually.

All simulations of complex systems show that, if we are to make correct decisions, we must stop drawing conclusions about the state of the system from the state of a particular variable. This will also reduce the temptation to alter the model arbitrarily in the hope of being able to manipulate a system analysis. Because both a good and a bad state in a variable can be both things for the system, good or bad, depending on the overall situation. This is different, on the other hand, in connection with genuine sub-systems of a superordinate overall system. If they are intact, this also helps the overall system, and *vice versa*.

Regional development: Frankfurt, Taiwan, and Mexico

It follows that the two areas of land-development planning and transport planning in particular need to be approached in a new way. Building on the understanding that the traditional strategy of infrastructure development is incapable on its own of effectively influencing either the growth or the negative repercussions of motorised traffic, the Frankfurt regional authority [*Umlandverband Frankfurt* or UVF] got together with the transport specialists of Kaiserslautern University to examine the 'Effects of traffic management on the Rhine-Main region'. Their study, published in 1995, stresses one effect that is typical of the systemic approach but that for decision-making bodies clearly constitutes a new experience each time: 'The instrument obliges all concerned to deal with a series of (potential) connections that in other cases would probably have been easily overlooked.'

With the uncontrolled growth of huge cities on the Chinese mainland in mind, the regional planners of the University of Taipeh were interested in developing a Sensitivity Model for the area around their capital city that (particularly after the severe earthquake of 1999) could be seen as pointing the way for future land development. In particular, an attempt was made to bring the precarious transport system under control by means of improved self-regulation (see fig. 80).

The most interesting thing to come out of this was the recognition that the stemming of growth aimed at with a view to conserving resources (with preference being given to small-scale structures) can be thoroughly compatible with increased economic prosperity, provided that the interests affected are persuaded to agree as a result of the connections having been rendered visible. Using the example of the key tourist resort of Ping Ding, north of Taipeh, which stood as prototype for a series of similar municipalities, it was possible to show, through a series of partial scenarios and their simulation, how successful this course of action had been.

fig. 80: A few minutes' walk from Taipeh's palatial Grand Hotel you will find this concrete monstrosity. Here, as in all the world's fast-growing urban agglomerations, proliferating traffic is the visible outcome of linear thinking.

In connection with applying the Sensitivity Model to a country on the verge of economic take-off such as Mexico, it is similarly a question of balancing ostensibly irreconcilable demands upon economic growth, hydrologic balance, excessive population drift to urban areas (Mexico City is now home to 20 million people!), the growing gulf between rich and poor, touristic regions left to nature, and worker emigration to the USA and meeting such demands in a way that will put the country on course for sustainable, self-regulating development. Here experts from the German development agency GTZ, the 'Company for Technical Cooperation plc' [*Gesellschaft für technische Zusammenarbeit GmbH*], working in conjunction with a group of decision-makers in the area of regional planning in Mexico, are looking to use the Sensitivity Model to reach solutions that can then be implemented. However, because of the occasionally conflicting interests of those involved, as well as developing efficient solution strategies it is necessary above all to bring the model's mediatory aid to bear on rendering visible the connections discussed at joint meetings.

Environmental planning and waste disposal

The Graz engineering practice of Friedl and Rinderer, in collaboration with the Austrian Research and Environmental Engineering Association (AREEA) and Voest Alpine Medical Technology (VAMED), has carried out a whole series of projects with the Sensitivity Model. In connection with their investigations into environmental technology in conjunction with urban planning, the people operating the model very quickly found that technical and economic optimisation can be achieved only through the systemic approach: 'The high degree to which the human sphere can be influenced and the large number of active elements call for a new kind of examination of actions proposed with a view to making optimal overall use of an urban area by allowing for how it will behave as a system.' This has made it possible to develop various solutions in this field: for Wels (in Upper Austria) a transport and urban-development concept, for Kuala Lumpur (Malaysia) concepts for inner-city traffic-calming, refuse disposal, and cleaning up a polluted river, and for Bangkok (Thailand) ideas for a holistic environmental-planning scheme.

In the words of Emmerich Friedl, who headed one of these projects: 'Our inter-disciplinary approach here took particular account of the fact that planning and administrative departments must themselves exhibit structures possessing cybernetic system properties; only then can all the advantages of the Sensitivity Model be exploited to the full.'

Healthcare and senior-citizens model

With AREEA recommending that in principle the Sensitivity Model should be used in practice as the main component of a dynamic planning process, the same group drew up the 'Hospital 2000 Manual of Expertise' [*Know-how-Handbuch Krankenhaus 2000*]. The specialist journal *Clinicum* noted in this connection that previous hospital reforms, though looking very splendid, had often remained completely without effect 'because a hospital constitutes an interconnected system. The Sensitivity Model put forward by VAMED AG and its team of experts from the fields of medicine, nursing, business, and technology for the first time depicts the mutual dependencies of individual elements in hospitals. Using a computer program, it is now possible to represent, within a short time, a wide range of different versions of how a hospital should be run – for instance, showing what will happen if a particular area is separated off.' The president of Vienna's Academy for Holistic Medicine, Alois Stacher, a member of the core team, therefore sees this model 'as a fundamental tool for all hospital operators, because without this kind of map pointing the way no one can think of everything.' In the financial scandals that notoriously hit Vienna's General Hospital [AKH] and the Aachen Clinic, it became clear what sorts of mistake could then arise.

Furthermore, in connection with the question of what form old-age provision is to assume in future, solutions are also being sought that on the one hand guarantee that people will enjoy good living conditions in old age and are on the other hand affordable. VAMED and AREEA have produced what they call the '2000 Plus Senior-Citizens Model', in the foreword of which we read: 'The holistic view was taken on the basis of a Sensitivity Model and for the first time shows the web of interconnections lying behind the "grey problem". The model has been used to create a pool of expertise that makes the structured knowledge of experts accessible to all.'

Holistic education and training

In order to close the gaps in our school and college education in regard to dealing with complex systems, the Sensitivity Model had been variously employed to develop new scholastic models as well as providing a useful aid to in-service training in the commercial sphere. One of the most remarkable initiatives was the conception of a new type of engineering course at the 'Higher Institute of Technical Education' [*Höhere Technische Lehranstalt or HTL*] in Oensigen/Solothurn in Switzerland. This seeks to foster a new culture of learning. The HTL places great stress on interdisciplinary project study geared towards the sum total of interactions of technological developments in practice. In this connection, the Sensitivity Model as biocybernetic management model furnishes a key thinking tool.

Principal Gander: 'We have no wish to stuff knowledge into heads as stock to be drawn on. The engineers of the future will need to solve real problems, not problems out of textbooks. So today's students will learn, from dealing with practical problems, to take not only technical factors into account but also ecological, social, and economic factors.'
When the new concept had been in place for three years, he wrote that the reorganised course had been accepted with huge enthusiasm by all concerned; the first graduates were highly satisfied with their empirically related expertise and had found a place in which to operate in the economy without any difficulty.

Detoxification

Here is another example from a branch of psychology, namely the implementation of detoxification procedures as presented by psychotherapist Jörg Petry in a 'Dry-dock systemic model' [*Systemmodell Trockendock*] at the Heidelberg conference of the 'Association of addiction specialists' [*Fachverband Sucht*] in 2001. According to Dr. Petry, the complexity of the detoxification process for drug addicts was making it more and more difficult to recognise the interconnectedness of the circumstances and to steer addicts in the direction of sustainable detoxification. Since both the patients themselves and the range of treatments available are complex in nature, drug rehabilitation is best seen as a complex problem-solving process.
In an excerpt from one of the partial scenarios (fig. 81) relating to in-patient detoxification, stabilisation of abstinence is shown as a target variable. From this starting-point, risk of relapse after residential detoxification can be enhanced indirectly by discrimination encountered during the patient's reintegration in society. In connection with the positive feedback loops marked in the diagram with a ⊕, which normally reinforce stabilisation, a nudge in the opposite direction is all it takes to trigger relapse with an equally self-reinforcing effect. Using the systemic approach, Petry sought to portray the events as a system model and (after closer examination of clusters of variables intimately affecting one another) to structure the overall network in such partial

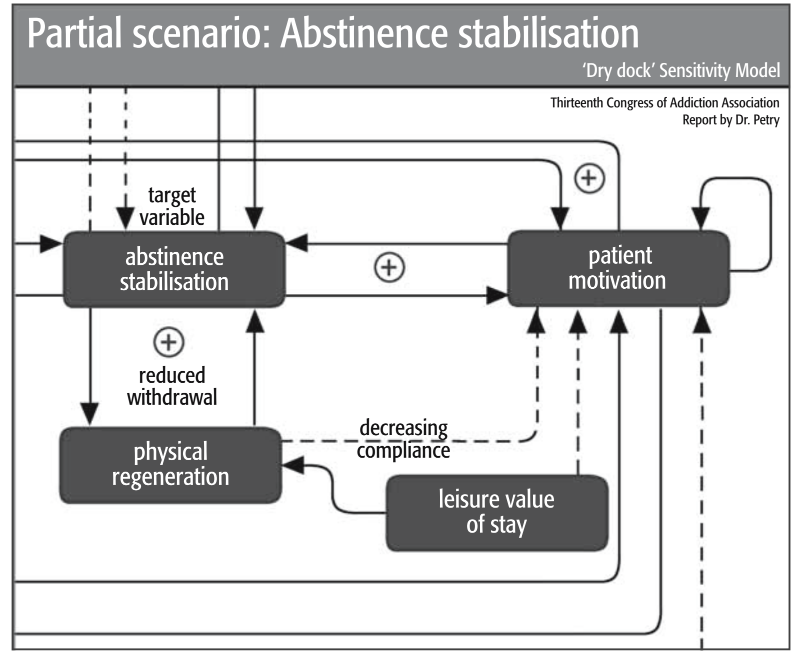


fig. 81: **Detox system model**; stabilising abstinence partial scenario (excerpt)

scenarios. That visualisation enabled Petry for the first time to capture the individual together with his or her immediate environment and to find new answers to a series of questions (regarding meaningful interaction, for instance) from that context.

Vandalism on public transport

In another project dealing with complex problems of corporate relevance for the 'Research, Society, and Technology' division of DaimlerChrysler AG, the systemic approach was applied to the growing amount of vandalism affecting public transport. The report written by Michael Steinbrecher and Tobias Holzmüller describes how this complex matter affecting the corporate sphere can be captured systemically and simulated with the aid of our computer-assisted model:

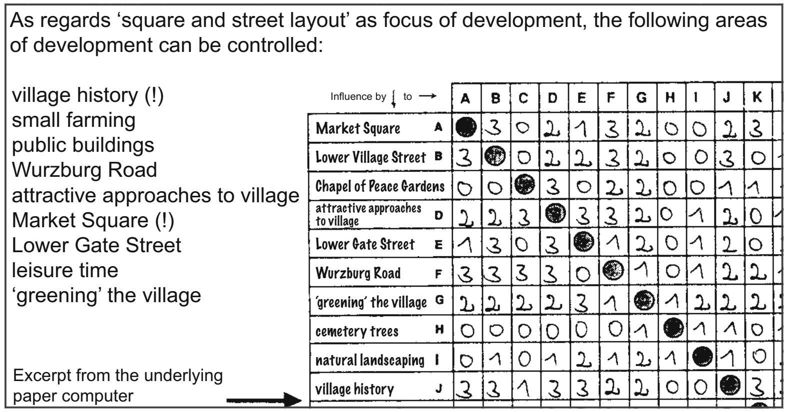
"The fact is, a phenomenon such as vandalism cannot be analysed in isolation from the social conditions within which it develops. The subject needs to be interpreted against the background of wider research into, say, 'Improving the social acceptance of means of transport'. For the Group, therefore, the question is: What options are open to DaimlerChrysler AG as a manufacturer of private cars, buses, rail vehicles, and aircraft in terms of designing products in such a way as to prevent vandalism? A key prerequisite for developing a counter-strategy to combat vandalism is therefore a deeper understanding of the structural patterns and connections that lie behind the phenomenon of vandalism [...]

One of the chief difficulties in approaching this subject was the extraordinary variety and interconnectedness of the individual actuating variables involved. For this reason, the systemic approach seemed a particularly appropriate way of tackling this question. Simulation makes it possible to analyse effects and interactions (i.e. direct and indirect influences on the way the system will behave) and to anticipate possibilities of taking action at the strategic level. In the light of the prevailing planning uncertainty and mounting complexity, this represents a major achievement."

Actually, in this particular case it is possible, instead of regarding a protective attitude towards means of transport as the system to be stabilised, to adopt the opposite method: analysing vandalism as a sub-system and directing one's strategy precisely at not enhancing its stability. The usefulness of measures and interventions is then judged by how much they are able to destabilise the workings of the system. This was in fact the goal of the simulations carried out. The principal outcome was a strategy that stepped back from adopting additional security and monitoring measures and instead created an environment that inhibited aggression. The strategy was successful - as it was also, incidentally, in the field of urban design with regard to reducing the crime rate.

Revival of the village of Geldersheim

Using the biocybernetic approach to planning as its basis, the non-profit-making Schweinfurt 'Information and Education Association' [*Gesellschaft für Information und Bildung e.V. Schweinfurt* or GIB] was commissioned by Würzburg's 'land-consolidation office' [*Flurbereinigungsdirektion*] to draw up, in consultation with the inhabitants of Geldersheim and as part of the public-participation initiative for village revival, a village model that accorded with their desires and needs.
It was recognised that a village revival that looks to the future and sets out to be successful must have the support of the inhabitants. Consequently, the village-revival guidelines of Bavaria's Ministry of Food, Agriculture, and Forestry require that: 'Villagers shall in an appropriate fashion be thoroughly involved in the process of village revival from start to finish.'
The marked change in the rural landscape in recent decades particularly affects the village community and extends to the way villagers regard themselves. It is they who know most about the special circumstances and how they have changed. Their views and values make up the very context of the village community. All citizens contribute their ideas and suggestions with an equal right to be heard. Nobody or no one group (planners, administrators, landowners, presenters) dominates the communication and decision-making process.
For the inhabitants of Geldersheim with an interest in that process, this enabled the village as a whole (in all its variety) to take part. They analysed all the potential implications (cultural, economic, social, natural, and agricultural), and discussed how each factor was to be taken further. The results formed the basis of the village model. Then, using this model, participants were able to debate individual measures and projects in greater detail and draw up a list of proposals accordingly.
As time has gone on, more and more companies, municipalities, social groups, and organisations have become curious about the biocybernetic approach and opted, in the light of the shortcomings of traditional management methods, to pursue this course as a fresh opportunity.
More information about where the Sensitivity Model has been put to use in the spheres of business, politics, science, and planning and how the sys-



As regards 'square and street layout' as focus of development, the following areas of development can be controlled:

village history (!)
small farming
public buildings
Wurzburg Road
attractive approaches to village
Market Square (!)
Lower Gate Street
leisure time
'greening' the village

Excerpt from the underlying paper computer

Influence by ↓ to →		A	B	C	D	E	F	G	H	I	J	K
Market Square	A	●	3	0	2	1	3	2	0	0	2	3
Lower Village Street	B	3	●	0	2	2	3	2	0	0	3	0
Chapel of Peace Gardens	C	0	0	●	3	0	2	2	0	0	1	1
attractive approaches to village	D	2	2	3	●	3	3	2	0	1	2	0
Lower Gate Street	E	1	3	0	3	●	1	2	0	1	2	0
Wurzburg Road	F	3	3	3	3	0	●	1	0	1	2	2
'greening' the village	G	2	2	2	2	3	1	●	1	2	2	2
cemetery trees	H	0	0	0	0	0	0	1	●	1	1	0
natural landscaping	I	0	1	0	1	2	1	2	1	●	1	0
village history	J	3	3	1	3	3	2	2	0	0	●	3

fig. 82: **Geldersheim village revival system model, paper computer of holistic citizen participation**

temic approach has influenced scientific research is given at the end of this book, where I list the projects that (so far as I know) have been carried out with the aid of the procedure as well as publications that deal with it.

Perhaps it should be stressed that, up until 1990, all projects based on the Sensitivity Model were, as in the foregoing example, carried out purely manually. They include, among others, my major study for Ford (germany) that was published by Heyne Verlag in 1990 under the title 'Exit future' [*Ausfahrt Zukunft*]. The same applies to the 'Ecoland' and 'Rural Workshops' studies, the 'General Transport Plan for Frankfurt', the feasibility study for a big leisure project, the Frankfurt 'Pueblo', and studies for Swissair, the Swiss insurance industry, and a number of planning models at municipal level.

Not until 1990 did I and a number of computer scientists whom I had trained especially begin to develop the Sensitivity Model software described in this book, which in constant feedback with users has matured into the computer-assisted aid to mediation and thinking available today. Here it has been above all the very much faster (in comparison with manual application) execution and more reliable user guidance of the System Tools program that have facilitated this multi-stage process as well as networking with external colleagues, with swift visualisation of individual steps and documentation provided by the relational databank offering additional advantages.

20 • The way forward

One purpose of citing these practical examples has been to make clear the broad range of application of the systemic approach; however, I hope it will also show how actual requirements in terms of appropriate answers can in fact be achieved. Their span (all the way from national level to the immediate surroundings of the individual and from grand psycho-sociological topics to regional planning to management in light engineering) shows that the systemic approach depends neither on the size nor on the nature of the system concerned. 'Subject neutrality' in the thinking tools used in this connection was an essential prerequisite if actuating variables extending beyond subject boundaries (often the most important factors in connection with a system) were not to be held back by professional 'demarcation disputes'. I hope that will adequately account for my reluctance vis-à-vis various users to develop special versions of the systemic approach for particular areas of application. The fact is, only if the ideas of non-experts are included in finding a solution to a problem will that solution (and the time and energy put into finding it) be appropriate to the complexity of the system investigated.

Quite apart from this, it does of course sometimes happen, as a result of a preoccupation over many years with a wide variety of systemic studies, that in connection with certain corporate questions one automatically reaches different conclusions than those circulating in a sphere of expertise that judges matters in a non-interconnected way. The prospects that arise from this as regards a new, cybernetic shaping of our world and our environment are manifold. I should like to address at least some of these themes – the ones that seem to me most crucial as regards tackling the future in a better way with the aid of the 'art of interconnected thinking'.

Cybernetic environmental policy

That we are more than ever reliant today on achieving a systemic understanding of processes at work in our environment (and with them the activities of the human population) has to do not least with the rapid increase in the Earth's population, in its sub-systems, and in their interconnectedness. As hinted at in chapter 4 in connection with growth processes, biocybernetics supplies the following account of the resultant structural change:

If a population (or indeed the number of its 'products') passes from a stationary phase into one of rapid increase, and if in this connection the density of living beings or partial elements produced (this is a question of space available as well as of distribution within that space), the old form of organisation changes as a result. What used to be 'quantities' increasingly become 'systems'. From a certain point of density onward, suddenly one is dealing with a new interconnected entity – a system, in fact, where before there was none. From now on, as regards maintaining the new system (even if the components are still the same as before), different laws apply, namely systemic laws. Moreover, those different laws also apply to the sub-systems of the new system in so far as such sub-systems benefit from it and seek to survive along with it. In the public mind, a clear feel for this evolution in our co-existence with nature has found expression chiefly in local Agenda 21 initiatives.

For that reason, when our decision-makers face such problems, there is a particularly urgent need for reliable forecasts that will give (when it comes to implementing specific goals) ready access to suitable aids to argument in the debate with public opinion. It should be clear by now that the problems cannot be overcome by means of ever more detailed data capture. However, it also in the nature of things that the manner of prognosis must be different than had previously been expected, taking its bearings more from such cybernetic criteria as self-regulation, vulnerability to disturbance, irreversibilities, and limits and incorporating other scenarios that determine long-term development.

Strategies arising out of such a model will therefore quite spontaneously see their main point of departure no longer in simply intervening but in demonstrating possibilities of self-regulation. They will then bear a striking similarity to certain of the famous 32 stratagems of the Chinese, which are based largely on an interconnected way of thinking-complete with feedback controls and time lags.

It follows that interpretation of the goal of 'improved viability' for the sub-system 'human society' (independently of the environment as superordinate system guaranteeing that society's life) will of course involve wholly new politico-legal considerations. Not only direct but also indirect interventions in our lives (because of the damage they do to the system as a whole) will increasingly, as it becomes less and less possible to evade them, be punished as crimes. It goes without saying that a legislative reinterpretation of human activities must be preceded in our awareness by a corresponding ethical re-assessment that sees something reprehensible and not merely negligent in such indirect threats to public security. Bringing policy into line with the eight basic principles of biocybernetics (what we have called the 'basic rules'; see chapter 9) will have the effect of diminishing the otherwise necessary contribution of tough legislative interventions in favour of self-regulating creative solutions that will benefit us all. There are major challenges facing the European Union and its institutions here.

One of the keys to our future, for instance, is cutting energy consumption. Water (the basic element of all living processes) is the other. The two things together, working in conjunction, govern our climate and dictate its balance. In chapter 3 I showed as an example of non-systemic targeting how the human species has long pushed too much energy through its system, which in evolutionary terms is a retrograde step. With the privatisation of water supply currently being aimed at, a key element of life (water has been dubbed the 'oil of the 21st century') is now a key economic factor. With dangerous consequences, for commercialisation is not interested in sustainable development but in maximising sales. A fatal strategy indeed!

Cybernetic security policy

Beyond this aspect of an intact environment as guarantee of survival, our strategic considerations also impinge upon quite different security-policy questions, starting with the topic of vandalism touched in the previous chapter and extending to the current question of combating terrorism, where the cybernetic approach has always been diametrically opposed to the interventions proposed by hardliners.

The former President of the German Federal Criminal Agency [*Bundeskriminalamt*], Horst Herold, wrote to me some time ago about his efforts to base police data-processing on cybernetic principles and turn it into a system that could be capable of learning. In his view, holistic cybernetic ideas were very much more important and very much more effective than repressive, restrictive police actions.

In an article that appeared back in 1973 but is once again highly topical, Herold wrote already:

> "Today the urgent task is to subject policing and justice to processes that incorporate feedback controls of one kind or another, processes that regulate and optimise themselves. This will develop a capacity for learning that replaces repression by prevention, dogged persistence by dynamics, hypotheses by forecasts, and management by control. [...] We shall find that the circle of factors regarding as causing crime in the past needs to be substantially widened. [...] This extends (to quote some examples) into urban and regional sociology, into town-planning and architecture, and indeed into every sphere having to do with criminality and housing."

Herold's thesis has since received repeated confirmation from studies into crime-deterrent architecture carried out in the US and other countries.

According to criminal psychologist William Chambliss of Washington University, a combination of urban-planning considerations and training measures targeted at small-time criminals is capable of reducing crime far more effectively at a fraction of the current cost of prosecuting and punishing it. One the other hand it should be pointed out at least in passing that having the police and courts preoccupied with small-time criminality (as was the case in New York, for example, under its 'hardline' Mayor Giuliani) can only, ultimately, redound to the benefit of organised crime and corruption.

In a sensitivity analysis of internal security in Switzerland as a public and private function, Patricia Weiss used interviews with representatives of the different organisations responsible to study the mutually interconnected nature of the tasks of police and private security forces in an environment of crime and the drug scene, social tensions, and family culture. The complex structure of these links confirmed the views expressed above. In connection with allocating roles to the different actuating variables, surprisingly the drug problem emerged as a buffering variable while the crime rate and social tensions were the critical factors threatening to upset the balance. Factors that turned out to be highly active (in other words, they tended to control the system) were not only unemployment and the proportion of immigrants but also social change and the portrayal of violence in the media.

Herold stresses that cybernetics (which he regards as one of the most important scientific acquisitions of the twentieth century), with its theories concerning dynamic self-regulating and self-organising systems, furnishes the best way of examining such questions: 'Applying its findings must inevitably enable the police and the judiciary to behave in the manner of a living organism, which develops techniques for retaining its viability in a changing environment.' Since in a systemic way of looking at things the environment plays as important a role as the actual facts of the case (a circumstance that the vandalism study also revealed), the implication is that we should redefine criminal geography – with a view, for instance, to explaining the 'criminal magnetism' of certain spaces. Here our eight basic rules of biological design enter the realms of urban and regional sociology, city-planning and architecture, and the interplay between criminality and housing. It must indeed be possible to ascertain, in connection with future urban and regional planning, a 'what-if' relationship with regard to crime density as well as an answer to the question of how far human and architectural activities make crime a more or in fact less attractive option.

Strategies to combat international terrorism

Above and beyond such questions of internal security in the local sphere, the big topic nowadays and probably in days to come as well is the security of our society. With the attacks of 11 September 2001 on Manhattan and the Pentagon, the mechanisms of defence against terrorist subversion have entered a new dimension. The global activities of groups of fanatics and their amorphous nature make all conservative protective mechanisms seem inappropriate. At the same time it has become clear to many people that a problem as complex as that of suicide terrorism cannot be solved by simple, straightforward revenge attacks (by the old type of linear thinking, in other words), but that we have to start asking the 'why?' question; we have to look at the interconnectedness of the reasons and at how feedback control loops may eventually kick in – in other words, we have to tackle the cybernetics of the systemic context if we are to make any lasting change here.

This was precisely the strategy used against the German RAF [Rote Armee Fraktion] terrorism of the 1970s. Successfully, too, up to now. Without the cybernetic method consistently adduced by Herold we should have failed. Or as the former disarmament spokesman of the CDU/CSU parliamentary party in the German Bundestag, Jürgen Todenhöfer, put it: 'Had we proceeded with brutality and machine-gun fire against the RAF sympathisers demonstrating on Germany's streets, the RAF would still be in existence.'

So immediately after the 11 September disaster my team sought to tackle the whole highly complex business with our cybernetic instrumentarium, drawing up a system model that we called 'Prevention of Terrorism' and resolving, in conjunction with our computer experts, to carry out a system analysis of the interconnections at work here. One purpose of this was to address the following questions: What is the most effective way of avoiding further terrorist acts? Will it be enough to eliminate the presumed leaders of the fanaticised movement, or what is the likelihood of successors appearing immediately? What lies behind these attacks? Where are their roots and what nourishes them? What furthers and what reduces recruitment of suicide teams? Can the sources of hatred be made to dry up? What would be the side effects of

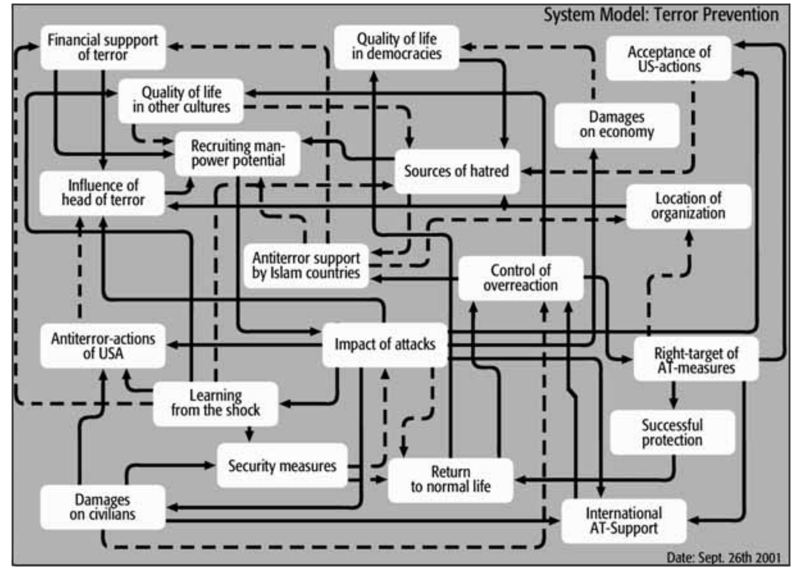


fig. 83: This provisional effect structure attempts to illustrate the complexity of the problem, using a few influence factors carefully checked in advance for their relevance to the system. Interconnecting a very strict selection of same-sense (continuous) and contrary (broken) effect arrows creates numerous self-reinforcing as well as self-regulating feedback loops that, when interpreted, indicate very different strategies than would a non-interconnected view of individual factors.

a counter-attack? What if this hit the wrong target? A systemic investigation addressing such questions would need as its 'therapeutic' main objective to discover what strategies would lead to or encourage circumstances in which different cultures, ideologies, and religions might co-exist in peace, enriching rather than destroying one another. Because if this does not succeed, the present situation will be a hotbed for every kind of social perversion: fanaticism, terrorism, oppression, crime, and warfare.

The beginnings of a Sensitivity Model have already given rise, on the basis of the dynamics of the system, to some interesting and sometimes surprising predictions and strategic indications. In addition, we simply recorded the known facts accessible to private research in connection with terrorist assaults and used our 'System Tools' program to reduce them to a manageable set of variables; we then linked these together in a network, just as we did in dealing with the other complex problems described in these pages. Our expectation was that here again the functions of the variables arising out of this interconnectness and their repercussions within the system would come up with different answers than would be supplied by isolated examination.

We also developed 20 detailed descriptions of variables, checking their relevance to the system. In this connection, even just the matrix of criteria showed that more than two-thirds of actuating variables (the keywords of which can be seen from the effect structure illustrated in fig. 83) are inaccessible to and cannot be influenced by external intervention. This characterised the system as fairly independent or self-sufficient and hence difficult to change from outside.

Matrix of influence and role allocation, which as we have seen give each actuating variable its specific position within the system, brought further surprises. Thus all the variables, because of their strong internal interaction, mainly cover the central, neutral range between the standards active, critical, reactive, and buffering. This kind of absence of more pronounced positions is typical of systems that move only slowly and scarcely evolve at all, with one impulse being immediately offset by another. There seems to be no real lever by means of which the 'situation' might be changed and still-dominant components nudged into producing a chain reaction capable of dissolving the system altogether. In other words, the terrorist system possesses a tough, viscous character, and bringing it under control (i.e. stopping attacks) calls for a simultaneous approach from a number of different directions and along a number of different paths. The art of achieving this depends to a great extent on understanding the web of links and the likely side effects of any action contemplated.

So there was reason to build up a provisional effect structure as well, one that would render the feedback control loops visible, in order to find out what would be the initial cybernetic 'responses' of the system model to various types of intervention. Such responses would be beyond the reach of linear cause-and-effect thinking. For instance, an initial analysis of regulatory cycles already revealed some striking behaviour on the part of the system, regardless of which of the 20 variables were removed therefrom or frozen in terms of their effect. Here, briefly, are the most important of those striking features:

- Influence of head: Eliminating the head of the terrorist organisation (Bin Laden, for example) would not change much. The relation of positive (self-reinforcing) to negative (self-regulating) feedback controls remains the same. Only their overall number has diminished. The same applies in respect of the variables 'location of organisation' and 'financial support'.
- Recruiting manpower: If this is removed from the effect structure, in stark contrast to the foregoing reaction all supporting feedback loops suffer almost complete breakdown. This might suggest that the terrorist system, which exploits the desire for a martyr's death, can in this way (though it needs to intersect with a great many connected threads) be brought to the point of collapse.
- Sources of hatred: If these are eliminated, again the chances of the terrorist system surviving will be seriously weakened. Since the interconnections are less dense than in the case of the variable 'recruiting manpower', the likelihood is that success can be achieved at less expense here than there. So it is worth looking for a ju-jitsu-type solution here.
- Counter-terrorism actions of the US: Surprisingly, whether or not these take place does not affect the system dynamics of the model. While there are clear repercussions (both positive and negative) on the quality of life of the American people, there are none on the capacity for action of the terrorist system itself. Indeed, it is already the case that a fresh victim of the terrorist threat is the American constitution in that the projected watering-down of civil rights places democracy itself (with its right to strike, demonstrations, press freedom, and free expression of opinion) in question. Other countries seem keen to follow the US example.
- Control of overreaction: This was the biggest surprise of all: without such control, in our model the terrorist system would stabilise over the long term with no hope of change. The cycle of terrorism (organisation – formation of terrorist teams – scale of attacks – organisation) remains, in the case of uncontrolled overreaction, the only self-reinforcing feedback loop, clearly protected by the remaining (43 altogether) stabilising regulatory cycles.

A particular problem as regards strategic considerations is that our own assessment of how members of a culture foreign to us will behave is always made exclusively in accordance with criteria that apply to ourselves. This leads to errors of interpretation. A behavioural reaction that can be counted on within our own society may not function at all in another society, and vice versa. So we cannot necessarily expect a strategy that in our Western civilisation effectively fights crime to be as effective when applied to a group of fanatics belonging to a different civilisation.

We therefore proposed interconnecting the reciprocal effects of these parameters in a partial scenario entitled 'religious fight', and to do so in such a way that they conform to the resultant evaluation, thus exposing the mechanism (probably incomprehensible to ourselves) that might offer a clue to solving the problem. It soon emerged that that clue certainly does not lie in the kind of reward/threat/argumentation pattern with which we might force our own criminal organisations/rebels/killers/Mafia bosses to submit but on a whole other plane, one that incorporates such elements as the substance of belief, martyrdom, etc.

My chief concern in this brief foray into the field of terrorism has been to demonstrate the potential of the cybernetic approach even in connection with such major security problems, and I would stress once again that this process of model-forming, carried out in the short time between 9/11 and the end of that month, is undoubtedly very incomplete as yet. That is why, in contact with the Technical Support Working Group (TSWG) of the US Department of Defense, we have put forward the suggestion that they and we jointly take the model further in the area of 'Terrorist Behaviour and Actions Predictions Technology'. This does at least hold out the hope that the systemic approach and applying cybernetic strategies may one day reach certain key decision-makers in the political sphere. To give at least some impression of the type of prediction involved, let us finally look at some of the conclusions that had been drawn by 26 September 2001 from the model constructed:

Preliminary conclusions from the sensitivity model »Terror Prevention« (date Sept. 26th 2001 – before intervention in Afghanistan)

- Whether the capturing of the »head of terror« (bin Laden or anyone else) succeeds or not – this has no effect upon the intrinsic dynamics of the terror system and its »sustainability«. Nothing will change. Therefore, any energy, effort or costs in this direction can be saved. Conclusion: stop the search for Bin Laden.
- The cybernetic pattern shows that the »sustainability« of the terror system vanishes with the sources of hatred. It would be wise and clever to choose out of these sources some which can be abolished without loosing face, or which may even rise our image in the world. Conclusion: finding a consensus with Islamic states (especially in the Palestinian/Israelian key question) about what could be changed to help both sides.
- Overreaction to terrorist attacks touches the highest sensitivity of the system model concerning long lasting effects. Without control of overreaction not a single competing positive feedback cycle remains that would be able to counteract the labile cycle between terror attacks and recruiting teams. Only selfregulating feedback cycles remain and stabilize the terror cycle via constant recruiting of new suicide volonteers. Conclusion: No unproportional war-like reaction. Restrained measures of the side effects which are well analysed.
- The »systemic role« of antiterror actions of the US and the behaviour of the system model upon those actions show that they seem to be – surprizingly – no lever to tackle the problem. They may not change the systems dynamics at all. This might be due to the special character of religious fight (the reason why we have started to simulate a partial scenario on this point). Conclusion: energy and money and lives can be saved – except if actions are necessary for pure protection measures.
- Recruiting of terror teams being the key variable. Without martyr candidates the whole terror system would collapse. However, just this variable is interlinked in many ways with the rest of the system. Any direct interference would therefore compensate itself. Thus it can best be minimized indirectly. Conclusion: Choosing ways »to take the wind out of the sails« of the fanatics, using their own arguments to make recruiting uninteresting.

- Choice of the right target is as important as the control of overreaction (see above). Direct links in the »effect system« of the sensitivity model show that wrong targets will create a chain of undesirable reactions like loss of support by other nations, especially the Islamic ones, rise the facility for recruiting new terror teams and other contrary effects. On the other hand it will occupy intelligence that would better concentrate on a more effective strategie. Conclusion: No bombs on civil settlements or other wrong targets.
- In relation to the victims and damages by hurricans, inondations, hunger and local wars – not to speak of the yearly toll of car accidents (wordwide 750 000 killed and millions crippled) the damages on civilians of terror attacks including those of the 11th September are just a fraction of these permanent worldwide desasters – with the same effects in the individual case. The big difference that horrifies us lies in the inhumane and criminal purpose of the fanatics. Thus, the level of traumata, panics and degree of desired security is mainly based on an special psychological reaction, which – in relation to other permanent dangers – does not correspond to the real size of the thread. Conclusion: Politics should bear this relation in mind and instead of increasing fear take adequate and thus most efficient decisions.
- Degradation of our democratic freedoms by surveillance and suppression as weapon against terror actions would be fully in the sense of the terrorists and fundamentalists. It would even escalate automatically via positive feedback cycles. Conclusion: No overreaction in this field either. Careful watch for free press, free discussion and the maintenance of differing opinions in the media. To save our democratic rights would remain the strongest bulwark against what the enemies of democracy dream of.

As regards this system model, which was deliberately called 'Terror prevention' rather than 'Combating terror', it will undoubtedly be helpful for the purposes of further processing that the kind of visual representation of systemic connections that our instrumentarium makes possible also brings together conflicting interests in the same network. As a result, the strategic indications that can be used for sustainable development come not from one side or the other of the parties involved (there is no winner, nor is there a loser) but from the representation of the system itself that has been worked out jointly. The consensus achieved as a result is then likely to be as sustainable as the strategies developed. It is also particularly important in connection with a subject arousing powerful emotions that the methods of fuzzy logic are used to incorporate qualitative actuating variables on an equal footing with quantitative data in the model constructed. By showing how they are interconnected (which in the normal course of events is often overlooked) a realistic picture can be given of the interconnected system involved here as well as of its dynamics of development.

Two views

'For US Defence Secretary Donald RUMSFELD the world has changed radically since 11 September. "This," he says, "is a fight against the biggest threat to civilisation since the campaigns of Attila the Hun."'

(Süddeutsche Zeitung, 25 January 2002)

'For philosopher Peter SLOTERDIJK an "incident in American skyscrapers" is not a serious reason why he should "think differently in terms of philosophy from the way he thought before". Looking back over the "disasters that littered the twentieth century", he sees "11 September . . . as tending to belong in the class of scarcely perceptible minor incidents".'

(Die Welt, 21 January 2002)

Experiencing complexity through play

I have already stressed how important it is to convey systemic behaviour not in cryptic similes but in plain text. It is only through our everyday language, by getting away from number and letter codes (inaccessible to semiotics), that as regards capturing and portraying our complex world we come another step closer to the genetic code of our brain cells. Part of this is that the use made of computers does not lose its way in information networks that are becoming less and less transparent and more and more unmanageably large – and certainly does not become misuse in that computers are asked to furnish oracular extrapolations. A simple desire to bring about some improvement here partly motivated our search for new avenues of software development. It was a question of making the leap from deterministic projections and closed simulation models to a biocybernetic interpretation and assessment of how systems behave. And doing so not in a purely theoretical way but for practical purposes – to give us a handle, as it were, on dealing with complexity. I should like in what follows to show that we can make a major contribution here by going further and introducing the element of play as learning process for pattern recognition; the phenomenon has been referred to as 'edutainment'.

In my lectures and seminars I have repeatedly found that, confronted with complex processes, people do not feel up to tackling them in an interconnected fashion. Even where they understand the need for a systemic approach, they shrink from applying a strategy that takes account of the system's interconnected reactions. This is quite understandable in view of the 'classification universe' that exists in their heads. Both the interdisciplinary approach called for and the unaccustomed inclusion of interlinked effects and repercussions in place of one-dimensionally oriented inferences give rise to a kind of mental blockage. People feel lost. However, like many things interconnected thinking does not simply drop into your lap. It has to be learned, and it takes practice. Not for nothing does this book have the word 'art' (in the sense of 'skill') in the title.

So what is the best way of opening our brains up to accommodate complex processes? Well, as we said in chapter 8 'Recognising complexity', the same way as we learn anything: through what in management we call 'learning by doing', through experimentation, designing things, trying them out; this is the essential prelude, be it in painting, in sculpture, in acting, or in music, to acquiring skill. In contrast to science, every true art requires not only intellect but also sensitivity, emotion, an ability to recognise patterns, a feeling for analogy – briefly, all the activities attributed to the right half of the brain. It also calls for a certain resonance with the body and with its senses and motor functions. Only then will we, in our activities and decisions, start to resemble a

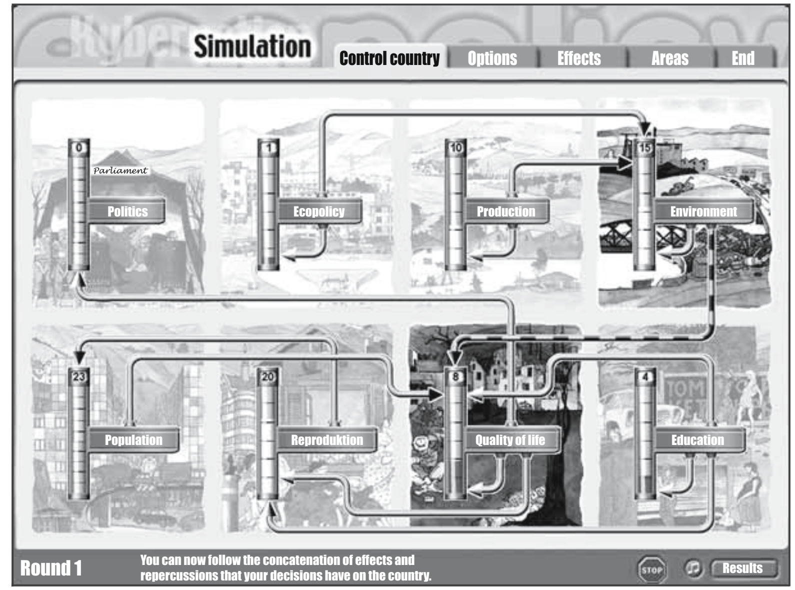


Abb. 84: View of a simulation run in ecopolicy®. The game's Introduction begins, 'We are living in an increasingly complex world. If we wish to understand it, we need a new way of looking at reality. Many things are connected that we see as separate. And often the invisible threads underlying things are more important as regards what happens in the world than the things themselves. Because as in reality it is possible, given the interconnectedness of effects, for things to go utterly wrong in a place where no intervention may have been made at all. The system's own dynamics have taken over. The fact is, wherever we intervene the effect of our intervention spreads, seems to peter out, then crops up somewhere else or somehow, taking a detour, 'feeds back'. Find out through play what it means to make correct (or incorrect) decisions in an interconnected system.'

complex system ourselves. It is the first prerequisite for seeing the whole world as a system. Unfortunately, though, precisely this kind of linking together of the two halves of the brain is driven out of us from our very first day at school. That is why we need to help our left brain (and hence our verbal/logical habit of thinking) to dare to make the leap out of the 'classification universe' to which it has become accustomed and into the 'relational universe' that is more familiar to the right-hand (more intuitive) half of the brain.

To help towards this goal, taking account of the findings of learning biology I designed a strategy game that has now been developed further; starting with a 'paper computer' using cardboard discs (the board game *Ökolopoly®*), this has become the interactive CD-ROM *Ecopolicy®*. Offered via the Internet for over a year on the German television programme 'Planet E', this strategy game attracted viewers with a thirst for knowledge to take part in a competition for the best performance in dealing with complex problems.

In this game, eight normally separate areas of a human environment (politics, production, environmental pollution, quality of life, redevelopment, public information, birth rate, and population growth) are linked together to form an overall network (see ill. 84). Using the examples of an industrialised country named 'Cybernetia' (Europe), a country on the verge of economic take-off named 'Cybinia' (South or Central America), and a developing country named 'Cyboria' (North Africa), those areas are linked together by different (usually non-linear) mathematical connections in such a way that every decision brings with it a chain of effects and repercussions – connections that can definitely, in principle, also occur in reality. The chain of action, starting from the individual spheres of life, arises out of simulations of effects and repercussions, with the state reached by a particular sphere each time immediately provoking fresh changes elsewhere.

In this way the state of a country changes from round to round of the game, as can be followed in the current balance in enlarged details of the particular sphere concerned and evaluated in the final balance. The overall course of the simulation can also be re-created in a separate animation. Whether a person succeeds in the game therefore depends entirely on his or her foresight and fingertip control. The fact is, many decisions that look positive at first may turn out to have been mistaken. The learning process associated with this 'edutainment', which eventually leads the 'player' to empathise with the initially impenetrable interplay of reciprocally connected effects, usually proceeds in four steps:

- Step 1: The player tries to get by with apparently sensible interventions designed to improve the situation. The results are usually unexpected setbacks, leading to failure.
- Step 2: In a second attempt, the player conceives an interest in the nature of the repercussions provoked, taking a look behind the scenes before reaching decisions, trying to imagine how one sphere will affect another, then selecting his or her strategy.
- Step 3: The player embarks on a voyage of discovery, becomes involved in the individual spheres, gleans from zooms and animations deeper insights into the circumstances that the chosen strategy has brought about. If the player is successful, the programme of the game becomes open to creative design.
- Step 4: The player starts to alter the systemic structure of the country, its starting-conditions and repercussions (the possibilities are endless here), thus learning more and more about the behaviour of complex systems in general and what allowances must be made in dealing with them.

Nearly everyone who plays this strategy game does indeed find that traditional thinking very soon leads to disaster and that several hostile coups have first to be undergone (players make much the same mistakes as the experts whom Dietrich Dörner invented for his Tanaland experiment, as we saw in chapter 2). As soon as he notices that each intervention in one area interconnects with other areas, taking on a life of its own, so to speak, and developing a separate dynamics, he ceases to experience the 'look behind the scenes' as a burden and discovers that it is in fact a means to cognition. In this way, *Ecopolicy®* is able to demonstrate the effects that characterise complex open systems, which makes it (despite its pronounced foreshortening of reality and consequent lack of precision) a better tool than conventional projections. Above all it clearly shows how, in interconnected systems, indirect effects also (and particularly) play an important role.

The unusual success of this game (the first version of which was chosen by the German weekly Stern as its 'Game of the year' back in 1985, while its multimedia successor was awarded the Comenius Medal in 2000) shows that using the experience of play to provide access to the dynamics and behaviour of complex systems is something that attracts wide interest and clearly presents possibilities of expanding awareness in a way that would be very much harder to achieve using other media (books, films, etc.).

Just as in *Ecopolicy®* a transparent simulation serves as a rehearsal for strategic ideas regarding entire countries (and that decision-making processes on this scale can indeed be captured in all their complexity is shown by our UNESCO study of China's Tjanjin region, with its population of 11 million), the same tools can be used equally well for the specific problems of one individual. So it seemed logical to follow that simulation game with another, developed along similar lines. Except that this one portrayed not a country but a single person as an interconnected system and was designed to give a better understanding, through play and simulation, of how the human organism would react to different interventions.

The aim of this undertaking (named *Humanopoly*®) was to promote holistic consciousness-formation by offering, through play, tangible experience of the interactions of the immediate personal environment as well as of a person's 'inner life' in the twin areas of human ecology and physiology.

Human ecology	**Internal functions**
– diet	– perception
– social relationship	– hormonal balance
– sexuality	– autonomic system
– family	– circulation
– career	– digestion
– leisure	– organs
– type of activity	– immune defences
– information	– lifestyle
– environment	– health
– way of thinking	– wellbeing

Given the complex dynamics of the way the game progresses (it draws on the latest findings of learning biology and system cybernetics), the idea is that the links between these variables should be able, directly and indirectly, to produce both psychological pointers and strategies for living. It is a further attempt to deal, through play, with complexity (this time the complexity that exists within ourselves). So far, however, it exists only on the drawing board.

Over and above its benefits in terms of practising interconnected thinking, there is growing interest nowadays (particularly as regards this more socio-psychological sphere and its complex processes) in professional application of the System Tools program. This not only concerns the implementation of actual courses of treatment (e.g. the detoxification therapies touched on in chapter 19); it is also relevant with regard to a holistic approach to medicine generally (a 'cybernetic medicine'), to which I now turn to round off this brief glimpse into the future.

Reflections on a cybernetic medicine

In connection with our preoccupation with complex problems and how we might learn to understand them, preceding chapters of this book have dealt almost exclusively with the complexity of the world around us, with pressing external questions of economics, ecology, and politics. Here I want to consider our own complexity, which ultimately concerns us far more directly. I am talking about our personal health – in other words, about considering the individual organism as a complex system. The fact is, just as in connection with those external problems, so too with medicine: superficial, non-interconnected strategies are very much the order of the day. My plea for interconnected thinking is therefore directed at our way of regarding problems that affect our own constitution, such systemic disturbances of the human organism as cancer, AIDS, circulatory disorders, allergies, and hereditary defects in the form of abnormal developments – things that purely linear thinking directed at a specific objective will probably never overcome. Yet particularly in medicine, which is after all concerned with the very foundations of cybernetics (namely, biological regulatory cycles within the organism), interconnected thinking is in paradoxically short supply. On the contrary, specialisation is even gaining ground. Yet we will never do justice to the essential nature of biological mechanisms unless, as in the outside world, we gradually come to recognise and respect existing feedback loops with their complex interactions, unless here too we protect, exploit, and benefit from such regulatory cycles as are already present – instead of ignoring them and eventually (often far too late) having to replace them by means of costly interventions.

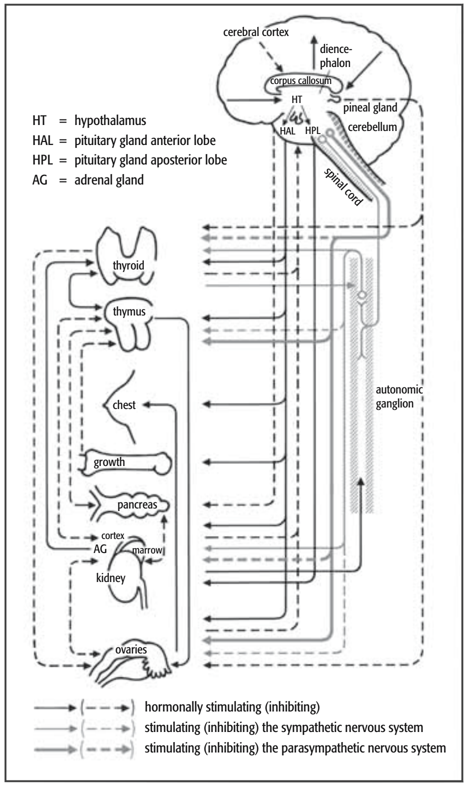


fig. 85: **Interplay of hormones**
Some of the nervous, humoral regulatory networks operating in human beings to hold body, mind, and spirit together.
The schematised network illustrates four areas in which our hormones alone play a part in all biological orders of magnitude while at the same time operating in so close a relationship to one another that it is often the selfsame chemical substances that tip the scales here:

1. Their function in connection with brain activity, with thinking and learning and processing sense perceptions, the object being to tailor our behaviour to and cope with the outside world.

2. Their cybernetic mediating role in feedback with one another and with such central control organs as the hypothalamus, which consists in bringing the human being into harmony with his or her psycho-physiological requirements, which is unfortunately (in the stress reaction, for instance) not always successful.

3. Their steering role in the genetic-enzymatic processes (e.g. as 'inductor') and their concomitant influence over the organism's defences and the way it adapts to a polluted environment, new strains of bacteria, new materials, and new habits and rhythms of life.

4. Their significance as indicating and reflecting physical and mental processes in patients. Still, unfortunately, a dream of the future. In principle, we already have access to therapeutic possibilities, but the gaps in our understanding of the complex dynamics of a human being's overall hormone pattern mean that we all too often find ourselves intervening to no purpose.

In future, then, as with our economic and environmental policies, our health policy too will need to be guided by the inavoidable laws of complex systems if it is not to be doomed to fail. Currently, in Germany, we lose 600 million working days to sickness each year. What this means is that increasing reliance on medication and technology in a context of ever more costly, ever more perfect medical care have clearly had little impact on the quality of our health. Average life expectancy, too, which increased dramatically in the first half of the twentieth century, has risen only marginally in the last 30 years. People in the highly developed industrialised countries may be living longer than before, but they spend more of their lives being ill.

So it is clear that, as in many other problem areas in our civilised society, in the health sector, too, no matter how great the technical outlay, it will do us no good if we miss the core objective of keeping our health. And that core objective is the harmonious interplay of the many different biological processes at work in the organism and how they interact with the organism's environment and fellow humans. Not, be it noted, by disturbing or even destroying existing feedback controls and replacing them with technological interventions but by making efficient use of them and thus remaining true to the basic rules of viable systems. Unfortunately, we are still a long way from following this course.

For some time now we have looked at health in terms of the laws of the market, believing this to be the best way to tackle these highly complex phenomena. However, if we consider the market as a network of interactions (as the Giessen-based communications researcher Bernulf Kanitscheider has done), it has its own dynamics, certainly, but no goal, despite consisting of many individual targeted intentions. This lack of an idea of where it is going is something we came across in chapter 2 as the first cardinal error in dealing with complexity. Attacking the 'disruptive factor' itself (rather than using the cybernetics of the system for the purposes of self-regulation) means, in this market-oriented medicine, targeting obvious sub-goals and operating at the costly level of treating symptoms. It is a method that as well as being expensive is also non-sustainable in that it misses the overall aim of improving preservation of health. So if we look at the development of medical management from the standpoint of biocybernetics, we have to conclude that certain of the methods of modern medicine and hygiene, in setting out to combat superficial problems in the short term, frequently intervene one-sidedly in a biological equilibrium without at the same time taking responsible precautions with regard to accompanying changes in the overall structure. Consequently, it often happens that connections are obscured and real solutions postponed to another day.

Certainly, this approach to problems cannot simply be exported all over the world and applied to other habitats than that of the industrialised countries of the West. For instance, the introduction of our orthodox academic medicine constitutes a major problem for many developing countries. One reason is that it runs counter to the real psychosomatic needs of the population. But even apart from this intellectual and spiritual realm, the achievements of many medicinal and hygienic measures pursued in isolation often cut both ways. For example, an initial decline in infant mortality brought about by such means can all too easily, if not accompanied by contraception, lead to a rapid increase in the population, which soon brings famines, epidemics, unemployment, and often even the collapse of the social structure in its wake – together with a very much higher general mortality rate than before. All these things spring from a narrow-minded belief in the efficacy of applying simple solutions to problems posed by a complex environment.

Every action concerning our health also extends far beyond the purely personal sphere to food supply, agriculture, air and water, and farther still to traditions, politics, and taboos, and from there back to people and their well-being. Our health therefore depends not only on the smooth working of our internal physiological processes or on direct external influences such as bacteria, viruses, poisons, and accidents. Rather, it is to a great extent the expression of an ongoing, multifarious interplay with the world around us and all that it contains.

So nature itself calls for a new and subtly controlling (that is to say, cybernetic) medicine. Instead of making massive interventions and fighting force with counter-force (in contravention of the 'ju-jitsu principle' and that of self-regulation) it could make an important contribution to supporting the self-curative and auto-regulatory properties of the body (rather than replacing those self-curative properties) as well as to the now highly effective and successful field of 'reparative' medicine.

However, this would mean moving away from diagnosing symptoms, an approach that actually seeks out disorders and therefore reacts only after the event (when it is too late) to outcomes of a linear-causal sort and turning increasingly to early pattern-recognition, i.e. to the kind of aetiological diagnosis that tries to get at the real, underlying causes and circumstances. This is the seam from which our society should mine the consequences with regard to sustainable psycho-social health. And that means ceasing to rely exclusively on the position that has been dominated for hundred of years by curative medicine – now become a monster that we shall soon be unable to finance any longer; there is a close analogy here with the call to turn away from costly 'end-of-pipe' technology in environmental protection – and alongside it (for we shall never cease to need it) giving a new and more important place to preventive medicine.

A new kind of answers

While our politicians are still arguing about whether interconnected thinking is really necessary, in progressive circles of industry and even among insurance companies (which, as we saw in the early chapters get to feel the effects financially) it has long since ceased to be a question of *whether* and become one of *how* interconnected thinking can best be applied. The examples given in recent chapters will no doubt finally have underlined how greatly it will be to our advantageous if we tackle future questions in the wider systemic context, whereas individual solutions (from tax legislation to subsidy policy and from the labour market to emission controls), be they never so perfect, ultimately lead up blind alleys, even when they come from the ecological camp.

The object of this book has been to demonstrate that today more than ever we are dependent on understanding events in the world around us (and the activities of its human population) in what I describe as a 'systemic' fashion. Indeed, I see the greatest risk in our continuing to view the world as an arena to be conquered with the aid of blinkered technical expertise, by tackling each project separately and concentrating only on getting the details exactly right, proceeding piecemeal without regard to overarching contexts. For this will place increasing stress on the world economy; its inevitable concomitant will be the progressive collapse of the vitally important interplay of all the many (and virtually free) regulatory and self-regulatory processes that make up our biosphere – on which, for better or worse, we are totally dependent, however sophisticated our technology. The more of these self-regulatory processes break down, the greater will be the expense of everything we undertake.

We have seen how, when we face the interconnectedness of our world, at first our threshold of inhibition rises. Dealing with any kind of complex process repels us; we prefer to concentrate on questions of detail and day-to-day business. Yet this is to pitch us out of the role of steersman and into that of the vessel adrift – adrift on an increasingly autonomous current of events. At the most recent meeting of the Club of Rome it was precisely this task that emerged as the greatest educational priority of the future: developing the intellectual aids and instruments to help us overcome that threshold of inhibition.

Another urgent need is to halt the self-generating spiral by which the type of progress that our civilisation may be said to have made up to now is outweighed by an almost automatic (and parallel) increase in civilisation's ills. And it is all because not only humans themselves but also their environment are misunderstood; they are seen not as complex organisms but as machines that can be fixed. Our civilisation will develop no further until we stop interfering in what are intricate systems with ideas that are confined to individual compartments. We need to start grasping the pattern of the particular system concerned and using *that* to identify (and make use of) opportunities for exerting cybernetic influence and control. Such influence and control will never work *against* but always *with* the system, be it a company, a community, an ecosystem, or an individual. Moreover, the cybernetic approach will always involve less effort as well as guaranteeing lower costs, self-regulation, prevention, and sustainability.

In any problem situation, until we cease to consider only certain sub-goals without seeing how they interconnect with the cybernetics of the system as a whole, we shall find our scope restricted. With questions directed at partial solutions, we are already dictating the style of our answers, forgetting our main objective: enhancing the viability of the system concerned. Yet that is the sole objective that exists at the start of our analysis of the problem; all the others must emerge from studying the system model. Only they will prompt us to ask questions that truly relate to the system, producing the new kinds of answer we so badly need. And only strategies developed from those answers can in turn be converted into sustainable action of a kind that is relevant to the system.

We still have a chance. That chance consists in more and more people beginning to see the world as an interconnected, living system, acknowledging the laws that have preserved its organisation through billions of years, and not merely upholding those laws but improving them and promoting them and wherever possible harnessing them in symbiosis rather than simply parasitizing them. For the fact of the matter is this: out of such interconnected thinking and doing, undreamt-of possibilities can emerge, even for a densely populated planet on which the dominant species, namely humanity, has an excellent chance of continuing to gain from the role it plays in the universal game of life and nature.

'We cannot command nature except by obeying her,' Francis Bacon once said. Today, ecology tells us he was absolutely right. Because anyone who does not play the game and play it properly, complying with the rules, will be thrown out. It is a process that nature has already used often to shed sub-systems that have got out of control. So it's not nature I'm worried about; it's us.

Acknowledgements

If this book makes sense, it is through the efforts of my wife and closest colleague, Anne Vester, who acts as my permanent copy-editor on everything I speak and write (both linear forms of communication) on the not exactly easy topic of interconnectedness. I also have her gift for organisation to thank for the fact that I was able to spend months concentrating chiefly on writing this book. Special thanks are due to our scientific colleague Gabi Harrer for many useful comments and tips from her project work, for her thorough supervision of pictorial matter, and for acquiring and adapting suitable methodological examples. Prospective lawyer and business-management graduate Andreas Ege combed the text for logical clangers and infelicities of expression, and Sonja Herbrich, besides successfully protecting her boss, tirelessly typed and corrected a series of fresh versions and assembled the bibliography.

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The now indispensable informatics back-up for the systemic approach would never have come about without the disinterested involvement

of two computer scientists, Josef Müller and Michael Stolz, who were prepared to accommodate didactic requirements that were often foreign to their normal field of expertise and who always came up with a solution whenever some new demand was placed on the software. I hope our co-operation can continue long into the future.

Just as the Bad Aibling Sensitivity-Model Study Group, with its plausible PowerPoint presentation of the method, inspired the title of this book, the very idea for the book itself came not from myself but (somewhat unusually, perhaps) from the publisher. So I am very much obliged to Jürgen Horbach for making me, at long last, pull together in book form the propositions and instructions concerning the art of interconnected thinking that were scattered throughout a host of seminars, articles, and lectures. In Stefan Bollmann I had a most understanding editor who despite my spending weeks off the job never put me under pressure of time. And the encouragements of my Club of Rome friends repeatedly gave me the strength to go through it again and to revise and expand the text once more for this official Report to the Club of Rome, in which connection I am particularly grateful to the man who has served as Club President for many years, Ricardo Diez-Hochleitner, as well as to Secretary-General Uwe Möller. And since this paperback edition [the German dtv paperback of May 2002/2005] includes not only some general updating but also a separate chapter devoted to my critical observations on the complexity of the nuclear-energy issue and gene technology as well as a new final chapter incorporating an experimental cybernetic analysis of the terrorist phenomenon and my call for a cybernetic medicine, I am deeply grateful to dtv for their ability to empathise with my constant corrections and the trouble I caused them as a result. Last but not least, I thank my six grandchildren for their patience and tolerance towards *The Art of Interconnected Thinking*, because they so often had to do without me while I was working on it.

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Register