Mental Models for Sustainability

by

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Coursework

Cleaner Production

(Waste Management)

For the Award of Master of Business Administration

Submitted 6. June, 1994

The Netherlands Institute for MBA Studies

Utrecht, The Netherlands

THE SIGNIFICANT PROBLEMS WE FACE CANNOT BE SOLVED AT THE SAME LEVEL OF THINKING WE CREATED THEM

SOURCE: D. HUISINGH

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1. INTRODUCTION: INTENTION OF THIS PAPER

Nobody who is aware of the problems of our time will deny that environmentally ones are among the most serious issues we are facing. However, if we ask what exactly the problems are and how we could solve them, that initial agreement disappears. There is a number of approaches to describe environmental issues and to develop proposals for solutions, be they on a scientific, morale, economical, political, philosophic, anthropological or any other base. Presumably the most comprehensive approach is the idea called ‘sustainability’. We find this word nowadays not only in publications of environmental pressure groups, but even in the preface of European legal regulations and the financial reports of multinational companies.

But what is sustainability? There are many different definitions around, many of them contain already conclusions and derived proposals for action. This very often results in a communication gap: many people - particularly when they have developed some kind of environmental moral - draw such conclusions subconsciously, but ‘the other side’ - quite often industrial managers - cannot follow these steps.

When I am now going to sketch some mental models relating to sustainability, this mainly builds on the experience I had with *Meadows ‘Limits to Growth’*, which caused me to develop a kind of feeling for environmental issues. In addition, ideas flow in from nonlinear dynamics, with variations like systems thinking, chaos theory or self-organisation. My experience with this way of thinking is that it allowed me not only to follow the arguments of environmentally aware people, whom previously I had considered to be unrealistic, but also caused me to take action myself.

2. SYSTEM BEHAVIOUR AND WHY WE NEED MENTAL MODELS

A system is a *‘group of things or parts working together in a regular relation’ (Hornby)*. The peculiarity about systems thinking is that it does not merely look to the ‘things or parts’, but also to the relationships between them. The system as a whole can have properties that are not founded in one of the parts, but in the way they relate together. Systems we find everywhere, as the following section shows. A human body behaves different from a bare accumulation of water and minerals, and a stock exchange market shows dynamics that we cannot understand just by looking at individual transactions.

There are two reasons why I think we need mental models and systems thinking to tackle environmental problems:

- The first one is that to understand the whole complexity of the issues we face, we cannot rely any more on the analytical approach which tries to understand something by examining the details, but we have to take a look at a broader picture.
- The second reason is that existing mental models - of managers, politicians, consumers, of everybody - influence to a large part the decisions being made and therefore this models are part of the problems itself. The ‘unlearning’ of old models and the provision of new ones therefore is part of the solution.

2.1 The House and the Bricks: 'The Big System' and Subsystems

Since we can consider systems as entities in their own right as well, they can become subsystems of a larger one, while in themselves again containing further subsystems. Finally, we can end up in considering the whole world as one big system. Figure 1 tries to provide a first glance on how we might imagine that.

We all know that finally every matter consists of atoms forming molecules, and on the other hand, everything we know is part of the cosmic system. Between these levels, all human and natural activity is placed, and all traditional sciences we know usually do nothing else than to focus on one specific subsystem of this whole. By mastering these parts, mankind have been able to achieve tremendous progress, and while the top half of Figure 1 shows natural systems, the bottom half refers mainly to the areas of society and technosphere - systems that were created by humans.

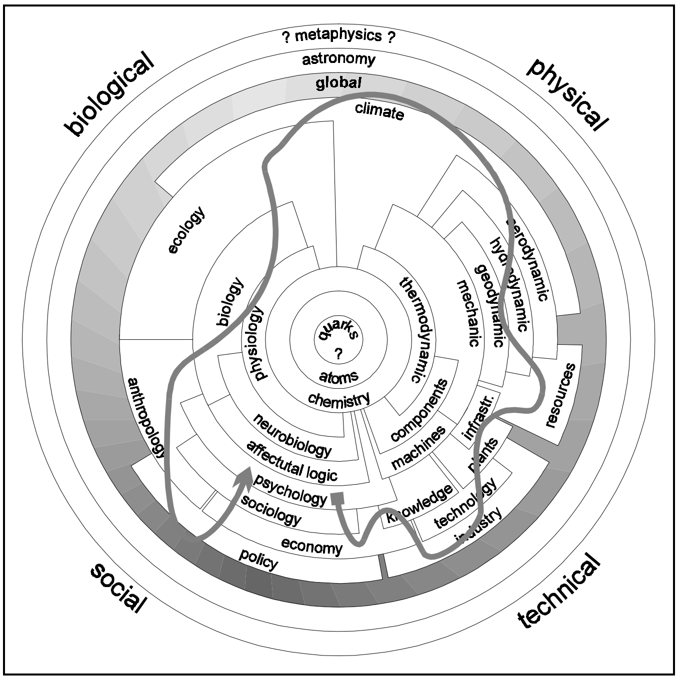

Figure 1: The World as a System

However, the environmental problems show a new quality: they go over the border of these traditional areas, as for example the curved path in Figure 1 indicates. Our patterns of thinking and decision making structures - which are based on psychological processes - form the way we build our society and by that the economy. This caused a tremendous industrial progress, requiring plants that use material and produce waste of many kinds. Direct or by infrastructures (like sewage systems or raw material markets) this draws on resources, that were created by dynamic processes on the earth in ancient times. This as well has an impact, for example, to our climate, that in turn affects ecological systems. Since we ourselves still are based on biological processes, anthropological consequences will result. Finally, whether reactive or as part of an avoidance behaviour, we will get political impact - not straight forward, but along a very puzzling web of causal relationships - once 'around the world'.

2.2 The Mortar: Mental Models and Systems Thinking

Unfortunately, these complex considerations as shown above, are in themselves good for not much more than just a philosophical discussion. When we consider that reality is by magnitudes more complex - after all, we are dealing with the whole world - the situation becomes mind-boggling. But fortunately, the evolution provided the human brain with the ability to take a broader view, away from details.

When we hear good news in the radio about a company, we expect the share price to rise and may therefore quickly try to buy some shares. At this moment, we don't care about the thousands of other possible buyers who sit wherever, listening to radios, consisting, of transistors, where electrons may flow. We don't care about our bank's information system, the people and machinery involved, the details of a market structure, regulations concerning orderly stock exchange. Our perception just concentrates on two relations: good news raises the share price, and calling the banker provides us with ownership of these shares.

In thousands of everyday complex decisions, we use the knowledge of such relationships, which are called 'mental models' (*Senge*). We acquire these models by learning, a process that starts in early childhood and continues the entire life. Basically, we distinguish between three ways to learn (after *Deming* in *Calcutt*):

- by experience - if some events show a comparable pattern, we assume a relationship (putting the hand on the furnace causes pain)
- by being taught - somebody who acquired a knowledge earlier, communicates this to us (don't drive on the wrong side of the road - people have been killed by that)
- by theory - we know how different parts of a system work and draw conclusions (we know about market structures, so we expect stock prices to rise after good news)

Once acquired, a model is reinforced, if experience proves it to be successful, in the other case it is weakened and 'unlearned': devalued and forgotten, turned into the opposite or complemented by a more developed view. However, the use of mental models is such a basic part of our thinking, that we usually take them for granted and may mistake them for reality (although in the horse market nobody draws demand and supply lines to decide on an equilibrium price and a volume). We usually do not make experiments to challenge them. Even if there is some evidence against an existing model, this results in pain and therefore first the evidence is questioned (cognitive dissonance), before the model - a proprietary knowledge - is given up. This mechanism makes mental models very persistent against unlearning and causes what we know as people's resistance against change.

Systems thinking helps us to challenge and question our own models and to bring the processes of learning and unlearning to the surface of consciousness. This enables us to adapt to changing situations much easier. In addition, systems thinking provides some basic patterns of systems behaviour that are found in many different systems we face in reality. The identification of such patterns accelerate the process of learning and avoids common mis-perceptions of linear thinking. Linear thinking (quite the opposite to systems thinking) always looks for direct cause-effect relations, which in the complex reality often are not there, since the very way of how a system is configured determines its behaviour, not one individual part of it. Common flaws of linear thinking are, for example, the assignment of fault, the belief in single solutions, the ignorance of remote side effects of an action or the trend to cure symptoms instead of root problems (for a more comprehensive description, see *Senge*).

Recalling the complexity of reality, we see that we cannot describe one situation with one model, but have to apply different views, different interpretations, and not to forget, different levels of detail: like a camera zooms in and out of a landscape to switch from the broad view to a detailed one, we have to integrate understanding on all levels of systems and subsystems to achieve finally the appropriate decision for necessary action.

2.3 Mental Models and the Environment

But how does this all relate to environmental problems? As many already accept, our economic structure lies, at least to a part, at the root of these problems. To change this structure, however, we have to change the underlying systems: the decision making procedures and the managers participating in them.

The whole set of mental models together form a good part of ones personality, since it reflects past experience and the beliefs of 'how things are' (compare *Luffman and Sanderson*). Therefore, managers, as everybody else, rely for their decision making on their own models. They contain, for example, ideas about market structures, economic efficiency and expected macro-economic developments. In addition, there are some general patterns, like the cyclic up and down turns, the concept of generic strategies and of course the belief in never ending growth, which form their picture of how the world works.

If we want to achieve the necessary change without a forcible transformation of our economy, we must try to approach the managers models. 'Unlearning' of some of these models and replacing or complementing them by other, more long term oriented ones could have significant benefits in the process of an environmental reorganisation of our industries.

Currently, two approaches are common to do so:

- Sophisticated scientific theories (e. g. climatic models for the simulation of global warming) try to show the serious consequences of our current activities. The problem is, that managers have no time to understand these models completely and therefore - since the results contradict their basic beliefs - do not trust them. In addition, many of the scientific results and particularly the consequences for economy and society are not yet clear. This causes uncertainty, so the manager's mind falls back to old models: technology will find a solution, and finally the market will regulate everything.
- The other way to provide managers with a different mindset is to support them with moral or philosophic thinking: responsibility for the earth, for future generations and an inherent value of nature itself are part of most of these concepts. Many proactive managers have already adopted them, but when it comes to conflict situations with their old models, the latter tend to win: ‘‘High morale values do not help when our business ‘goes bust’ in the short term’’

In the following sections, I try to challenge some of the conventional management thinking and to collect some of the alternatives that I found so far in different sources and which helped me personally to unlearn many of the old beliefs.

3. BASIC CONCEPTS OF SUSTAINABILITY

3.1 What is Sustainability?

For many people, sustainability seems to be a big word that means everything and nothing, but it looks good on a PR-brochure. However, this does not us bring much further towards a solution.

To get started, I here recall the definition from a dictionary *(Hornby):*

*‘**sus-tain** [...] **1** keep from falling or sinking [...] **2** (enable to) keep up, maintain’*

Transferred to the environmental issues, the definition of the *Brundtland-Commission* (presumably the most quoted definition in an environmental context) is closely related to that view:

‘Sustainable development is development that meets the needs of the presents without compromising the ability of future generations to meet their own needs.’

This definition includes the main three aspects of sustainability that underlie the thinking of this report:

– sustainability is a mean to an end: to **fulfil needs**

– sustainability means maintaining this ability for the **future**

– sustainability includes the fulfilment **for all** presents, not only of some.

3.2 Three Basic Behaviour Patterns of a Resource

To link the above definitions to environmental issues, we combine it with a view of the environment which stems from NASA (quoted by *NIHS*):

'In general terms the environment can be seen as
a system of reservoirs and fluxes that link those reservoirs.'

To fulfil needs, we have to withdraw a certain amount from a resource's reservoir. This either can be limited, be refilled by a fixed flow or regenerated by the resource itself, so that the regeneration rate depends on the stock.

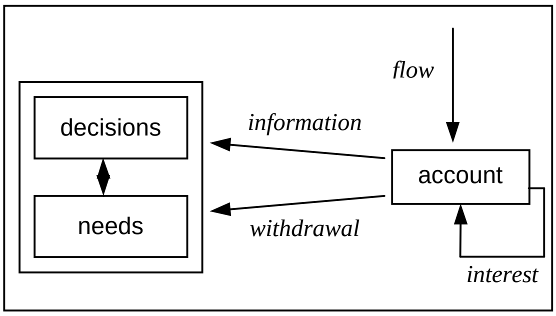

Figure 2: Structure of the basic model

To point out the basic principles, we use a simple financial model, not one of the usually very complex environmentally ones. If in consequence some of the conclusions are so obvious that they might appear silly, this is deliberate. Figure 2 outlines the structure of our resource: we assume, that a man who died left to his widow and their children an account for their living. Let the widow be just at the age of thirty, so she may expect another fifty years or so to live only from this account. When her husband died, there was some money in stock. In addition, there might be some constant flow (later on referred to as external regeneration), like from a pension fund, and the account might regenerate itself by bearing some interest (internal regeneration). The widow may or may not have a look to the balance of the account, and there are certain rules that guide her behaviour to withdraw money for consumption.

	A	B	C	D -E - ...
1	period	0 (start)	1	2 - 3 - ...
2	stock b/f	1000	=B8	
3	constant flow	=const_flow	=const_flow	
4	regeneration	=regen*B2	=regen*C2	
5	available	=SUM(B2:B4)	=SUM(C2:C4)	
6	request	50	=B7*(1+growth)	
7	conceded	=MIN(B6;B5*limit)	=MIN(C6;C5*limit)	
8	stock c/f	=B5-B7	=C5-C7	
9	const_flow	30		
10	regen	10 %		
11	growth	5 %		
12	limit	30 %		

Table 1: Spreadsheet for the simulation

The Graphs in the following sections were produced with a simple spreadsheet, which is shown in Table 1. The structure is as follows:

Column ***A*** shows all variables involved: the ***STOCK B/F*** of money at the beginning of a period, the ***CONSTANT FLOW*** and the flow from ***REGENERATION*** (interest) add up to an ***AVAILABLE*** amount in every period. A ***REQUEST*** can be made for withdrawal, however, the amount ***CONCEDED*** is limited by the available stock times a self-imposed ***LIMIT*** (which may be 100 % for unlimited withdrawal). Column ***B*** shows the starting position in ***PERIOD 0***, which is a fixed number for the initial stock and the initial withdrawal rate. The flow is constant all the time (***CONST_FLOW,*** given below the table). The regeneration rate is the stock at the beginning of each period times the rate (***REGEN***). The amount ***AVAILABLE***, reduced by the ***CONCEDED*** withdrawal, is carried forward (***STOCK C/F***) into the next period. There the same calculation is made, with the exception that the request now is a certain percentage (***GROWTH***) above the amount ***CONCEDED*** in the previous period. The same structure of formulas is copied 50 times to the right, so that a simulation for 50 years results. The charts in the following sections show the development of selected variables over all 50 periods. Changes are made in the four parameters ***CONST_FLOW***, ***REGEN***, ***GROWTH*** and ***LIMIT***, as well as in the initial values for ***STOCK*** and ***REQUEST***.

3.2.2 Use of a Stock

The simplest case is that there is only a fixed amount of money available, without interest and without additional inflow. Figure 3 shows what happens when there was an initial amount of 1000 (whatever unit) available and our lady increases spending every year by 5 % to cover increased needs and because the lifestyle requires it. Three different variations are shown: number 1 with an initial withdrawal of 30, number 2 starting at 50 and number 3 starting at 70.

The result is not surprising: the lifestyle will increase, while the stock is depleted at an accelerating speed, until it is finished and our victim has to starve. The initial rate of withdrawal makes no qualitative difference, it just shifts the time of starvation. Only if the stock is large enough to nourish her for the whole expected life time, she will not live long enough to see the depletion occur. Nevertheless, this is not sustainable because it leaves nothing for future generations. (Remark: we do not consider the case of social benefit, since in the end this could be a model for our current situation on the planet. The chance to receive social benefits from extraterrestrial sources is not very high, even if NASA sometimes wants to make us believing so).

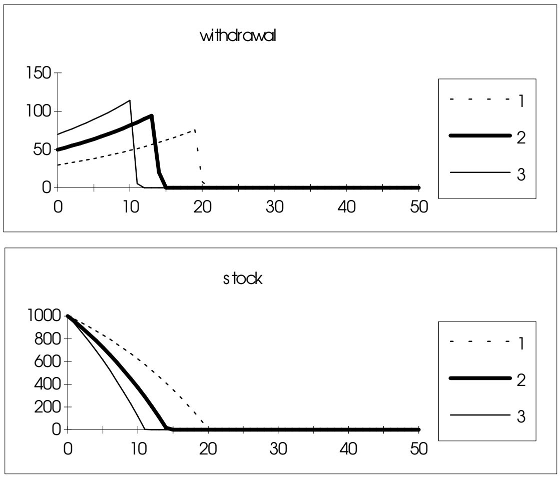

Figure 3: Utilisation of a stock

If we transfer the model to the environmental situation, we have the behaviour of the utilisation of non-renewable resources. Examples are ample: all mining resources like iron, oil or uranium behave in this way, but also some non regenerative carrying capacities like the one of soils for persistent pesticides. If no precautionary management of the resource exists, we have to expect a pattern of growth with a final collapse.

3.2.2 Utilisation of a Flow

Figure 4 shows the second basic case: the utilisation of a flow, which feeds into a resource. The difference to the first case is that we start with a stock of only 300, but this is replenished by an annual flow of 100. Again, we see a pattern of growth and a final breakdown, but now not to zero but to a long term sustainable level: the amount of inflow. If we compare the total amount of resource consumed at the end, all three variations are equal: the initial stock plus the cumulated inflow up to that point. The only difference in consumption is, like in the example above, the pattern in time.

Examples in the environmental areas may be the use of a groundwater stock: after using up an initial stock, the long term capacity decreases to the (usually much lower) sustainable level of regeneration, which, however, is independent of the stock level itself. Some carrying capacities, like for noxious but biodegradable substances, may show similar dynamics.

There are also examples of flows that cannot be put on stock: the usage of water from a river or the use of solar energy. In this cases, possible use foregoes by not using a resource, and the maximum consumption is achieved by using all available flow immediately (with the assumption, that this does not cause adverse side effects).

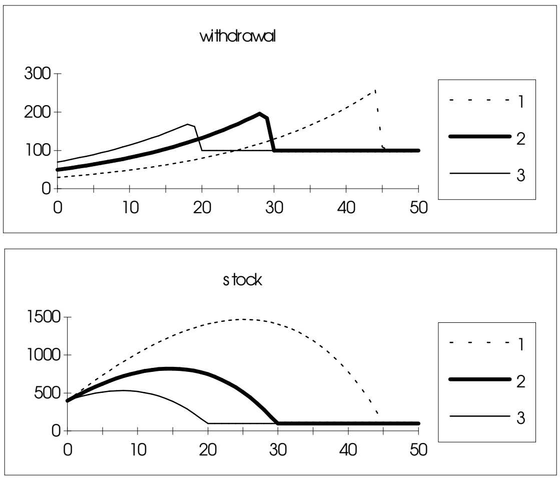

Figure 4: Utilisation of a flow

3.2.3 Regenerative Stock

The previous cases both assumed that there was no interest on the account. In the case now shown in Figure 5, we assume the account to start at 800, but to bear an interest rate of 10 %: the regeneration now depends on the stock left. The behaviour of withdrawal is still unchanged: 5 % growth every year, and an initial withdrawal rate of 30 (line 1), 50 (line 2) or 70 (line 3) per year. Now we end up with two qualitatively different situations: while the higher withdrawal rates again causes a breakdown, because - despite the interest being higher than the growth in usage - the stock cannot grow that fast because more than half of the interest is withdrawn every year. However, if we withdraw initially less than 40, more than 5 percent is left for the stock to grow and yields then ever increasing wealth - as it is the goal of the economic policy of every country.

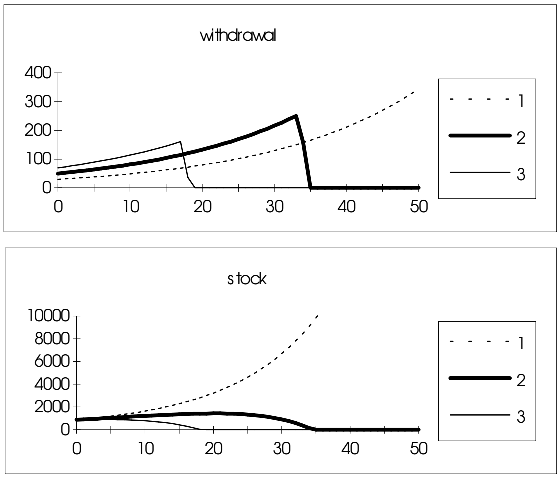

Figure 5: Regenerative stock

Most biological resources form regenerative stocks: fish in an ocean or animals to be hunted. However, they all have - unlike our simplistic example here - an additional upper limit that works similar to the constant flow example of 3.2.2. Unfortunately, mainstream economic thinking still implicitly assumes the simplistic case.

3.3 Managing a Resource - Managing Sustainability

3.3.1 Self-Imposed Limits

The financial manager will be grumbling already because of the short-sightedness that we assume in our examples. Of course, we have to assume that our widow knows something on financial matters, reads the account’s statement every year and limits her spending in a prudent way. Figure 6 shows the result: the conditions are similar to that in Figure 5 (line 2, with withdrawal starting at 50), but now the annual spending is restricted to 15 (line 1), 9 (line 2) or respectively 5 percent (line 3) of the stock. Now we see an additional pattern that we could not generate with the assumptions above: the long term stability of revenues, if withdrawal equals interest. Even the breakdown scenario is softened considerably: revenues go down slowly, not within one year as in the previous examples, because self-limitation starts much earlier now,.

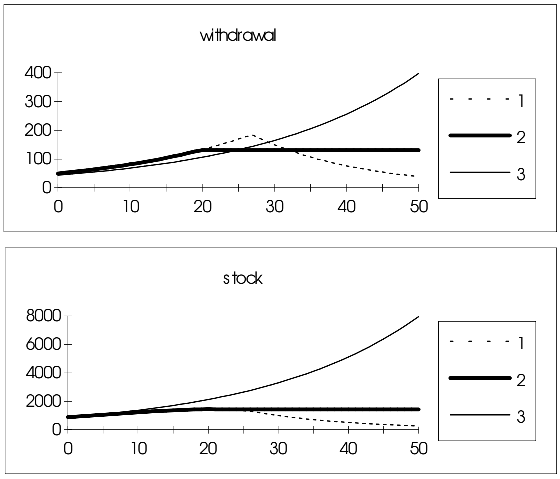

Figure 6: Limited withdrawal

Of course we could change the strength of limitation over time, for example allow initial growth along curve 1 and switch later on to a higher withdrawal rate - then of course at a higher constant level. This is basically a strategy that looks like ‘sustainable growth’, although in the complex reality, where we always have limits from other parts of the system, sustainable growth may be a contradiction in itself: only stable patterns can be expected not to hit new limits. However, if we feel limits in a soft way, so that there is enough time to slow down a growth pattern to a stable one without a breakdown, we still may call this sustainable.

Unfortunately, in the real world we have to look very intensively to find examples for prudently managed resources, at least if we concentrate on industrialised nations. Indigenous tribes all over the world are known to achieve this strategy, however, their opportunities of doing so are becoming more and more endangered now.

3.3.2 The First Danger to Sustainability: Uncertain Information

For coming nearer to the reality which our economic-ecological system faces today, we have to make our system a little bit more complex. Figure 7 shows what happens if we combine all three of the previously mentioned basic structures. The assumptions are: the initial stock is 500, we have a constant flow of 40 per year, an interest rate of 10 percent, an initial withdrawal of 50, growing at 20 % annually, but limited to 15 % of the stock. To show the dynamic behaviour, four variables are charted at once: the constant flow, the total flow (with internal regeneration as the difference of both lines) and the withdrawal refer to the left hand scale, the stock referring to the right hand one.

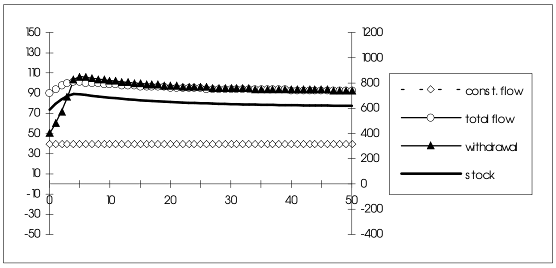

Figure 7: Adaptation without delay

The high growth rate lets the usage quickly rise to the total regeneration rate (external plus internal), show a slight overshooting, but stabilise eventually on a sustainable level where withdrawal equals regeneration.

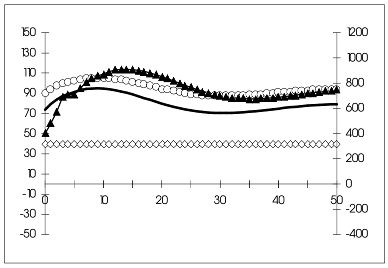

Figure 8a: 5 years delay

Uncertain information causes decision makers to wait with necessary actions or to make the wrong decisions in the first place that do not tackle the problem. Therefore, to simulate uncertainty of information, I simply introduced a delay: the limit now does not refer to the recent stock, but is calculated on basis of the stock some years before. Figure 8a - 8c show the results. A delay of 5 years (Fig 8a) causes oscillating overswing, that, however, eventually stabilises. With 7 years of hesitation (Fig 8b), the system appears to remain in permanent oscillation. Finally, with the decision shifted even further to ten years, the oscillation becomes self-amplifying (in managerial slang, we refer to this as ‘troubleshooting’ or ‘firefighting’) and causes the stock to become negative at the end.

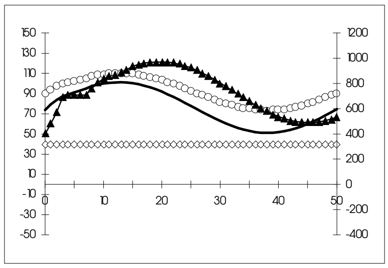

Figure 8b: 7 years delay

Of course, the time unit involved is not necessarily years. Similar system behaviour can be identified in the magnitude of seconds (for example at the initial contact stage between people, when they decide whether to like or to hate each other) or within weeks (when a company launches a new product and decides on marketing measures). However, most environmental problems have time scales in the magnitude of decades. If we compare our charts with the simulation results of *Meadows*, which are based on a much more complex model, we find similar time scales.

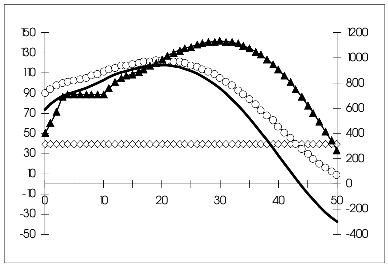

Figure 8c: 10 years delay

3.3.3 The Second Danger to Sustainability: Competition

The problem of most environmental resources is that they are still common goods: there is no price on them, so the ‘free rider’, taking as much as he can get, is at least in the short term best off. The sequence in the Figures 9a - 9e shows that. The model is now extended in the way that 3 parties run in parallel, but they share a common account. The conditions are similar to that in 3.3.1 (stock 3 * 800 = 2400, no external flow, 10 % internal flow, 50 initial withdrawal per party, growing at 20 %, a limit of 3 % of the stock for each, adding up to the sustainable rate of 9 %). Table 3 shows the assumed constraints for every run and the resulting cumulative use over 50 years.

	limits (% of stock)			cumulated withdrawal			
Figure	1	2	3	1	2	3	total
9a	3,0	3,0	3,0	4397	4397	4397	13191
9b	**5,0**	3,0	3,0	4604	2903	2903	10410
9c	**8,0**	3,0	3,0	4365	1932	1932	8229
9d	**2,0**	3,0	3,0	3874	5751	5751	15376
9e	**2,0**	**2,5**	3,0	4445	5535	6607	16587

Table 3: Outcome of a simulation of competition

In 9a, we assume cooperation, so that the behaviour is basically the same as in Figure 6 of 3.3.1.: constant, sustainable use, equally for all three parties involved. In 9b, party 1 is a ‘free rider’ and increases his own limitation to 5 %. The result is a switching of the system to non-sustainable behaviour, but within the time frame considered, at the cost of the others: the system shows the structure of a prisoner’s dilemma. However, the benefits of free riding are limited: in 9c the limit is further increased to 8 %, but since the resource now breaks down quickly, the free rider’s yield falls below the initial level - additionally causing severe losses for both the other parties.

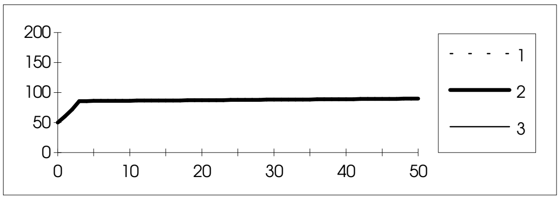

Figure 9a: All parties take 3 %

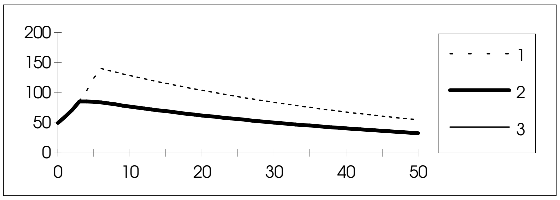

Figure 9b: Party 1 takes 5 %

9d shows the situation the other way round: party 1 reduces use, thus causing the system to switch to a long term, sustainable growth - however, the benefits are reaped by the others, party 1 loses. To prevent the reader from falling into cynicism, 9e shows a situation where the proactive player wins at least in comparison to the starting point, just by getting a second party to cooperate at least to some extent: the increase in overall system performance is enough to offset all deliberate renunciations. But still, the one taking the most finally ends up best.

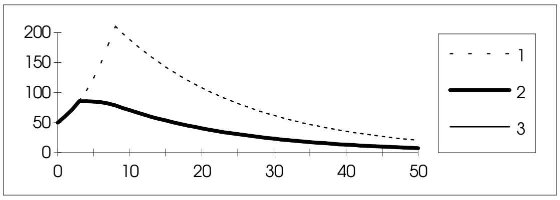

Figure 9c: Party 1 takes 8 %

This recalls the notion of competitive advantage, which tells us that not absolute, but relative performance counts. To take this into account, I made the final share of resource conceded for every company both dependent of its share of initial request (in business terms, we might talk about marketing efforts) and last periods success (let’s call it economies of scale). Initial stock is 2000, external flow 100, internal regeneration 5 %, initial withdrawal 50 per party, growth 2 % (1,99 for party 1) and self-limitation 5 % (4,9999 for party 2).

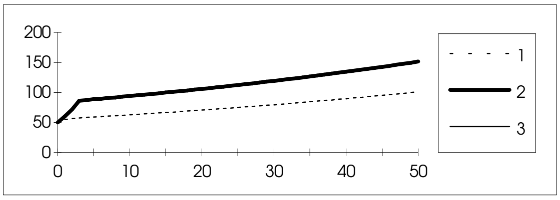

Figure 9d: Party 1 takes only 2 %

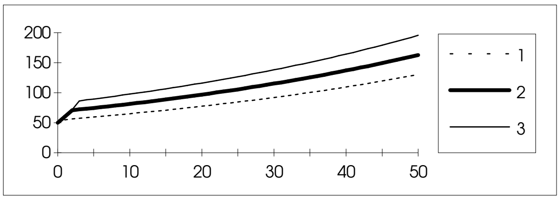

Figure 9e: Party 1 takes 2 %, party 2 takes 2,5 %

As Figure 10 shows, the amplification of the tiny differences is amazing: after 10 years, during which the growth rate is limiting the use, party 1 is 'pressed out of the market', because it's growth rate was slower, which cumulated to a severe disadvantage. In turn, party 2 and 3 show 3 years of explosive growth, until the resource constraint becomes a limiting factor. Now, over 20 years, party 2's disadvantage in utilising the resource begins to build up, until it finally goes out of business very quickly. The resource can recover again and allows 3 a sustainable growth, as long as the limit is not increased to a non-sustainable level.

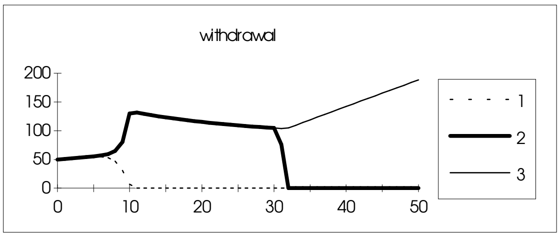

Figure 10: Amplification of success

What we could see in these small simulations is an inherent property of systems behaviour: although the system itself is very basic and consists of only a few variables, it is possible to generate a variety of typical patterns similar to larger systems. The last example demonstrated a case of symmetry-breaking: tiny little differences in an otherwise balanced system can amplify themselves and cause totally different outcomes, that nobody would expect if only the differences in the initial settings were considered. These two patterns (similarity of systems behaviour and symmetry braking) are basic findings of the mathematical branch of nonlinear dynamics (sometimes called 'chaos-theory'), a science that is expected to provide much to understand how complex systems like markets, ecosystems, living organisms or human brains are working. Application of models from chaos theory could give many more insights into the relationship of economy and ecology, and hopefully will also provide indications for solutions. However, there is not enough space here to elaborate further on those issues.

4. SOME THINKING TO BE QUESTIONED

The following sections illustrate some of the mental constraints that prevent us dealing effectively with our environmental problems. Where possible, I will try to relate them to the above basic models and to complement views or show flaws in the thinking.

4.1 The Limits of Our Perception

4.1.1 The Boiled Frog: Limitations to Recognise Slow Degradation

Our sensual system is designed to respond to rapid changes in our surroundings, but usually, it is difficult for us to relate the perceived impressions to an absolute standard. This characteristic prevents us in many cases from information overload and focuses our attention on acute dangers. However, the disadvantage is that we do not have a built in early warning system for slowly accruing problems, but become accustomed to processes of slow degradation.

Senge gives a nice parable for that pattern: the experiment of the boiled frog. If you put a frog into hot water, he immediately will feel the pain and jump out. If, however, you put him into cold water that slowly gets heated, he will not realise the problem until he becomes so weakened by the heat that he is not able to jump out of the lethal situation any more.

Fortunately, humans do not show that behaviour against immediate physical threats. However, in more abstract situations it is still there: the student, who delays study until the exam is so close that he cannot handle all the workload any more, is one example. Another one is the company that allows quality standards to erode until customers stay away and bankruptcy becomes unavoidable. In many instances, the basic environmental problems we face may turn out in the same way, if we are not able to notice the threats.

To do this, we can borrow the solution from the prudent student and the successful company. Both recognise the possibility of a threat, plan steps to overcome the problem, define fixed yardsticks to measure against and monitor progress - in short: they manage the danger. There are many environmental management tools available now. The task for the moment is to find ways to apply them systematically and to develop yardsticks to measure progress or retrogression.

4.1.2 Devaluation of the Future

Nobody is perfect. People smoke, they drink alcohol, and they put their lives at risk by irresponsible ways of driving. These are all examples where severe future disadvantages are accepted in favour of a small, often irrational present advantage. Partly, there is some rational explanation for that, which economists call discounting and which is further elaborated in the next section.

However, the relation of benefits to risk that people apply when they make such trade-offs seems to be far away from rational considerations. As a psychologist recently told me, there appears to be a much stronger force, similar to that one keeping the frog in the warm water, which is based on the way our brain operates. In terms of the affectual logic *(Ciompi)*, it may be that short term pleasure works on a different level of awareness, and as long as the need for that is not satisfied, the level of thinking that allows people to consider trade-offs on a rational basis is not operating at all. Rational thinking, however, is necessary when we have to evaluate future effects, to asses risks and even to allow people in remote parts of the earth their fair share.

If we try to draw a lesson from this situation, we may conclude that for sustainable behaviour it is important to fulfil the basic needs of the acting subjects. This refers not only to physical needs, but also to social ones. The stress situation that many managers have to endure does not seem to meet this requirement. The confrontational style that many environmental activists use in their communications and some of them even in their writing does not do that either. And of course, we cannot expect poorer people in the world to accept our environmental expectations, if they feel cheated - even when their basic survival needs are met.

4.2 The Market Will Solve It

Mainstream economic thinking states that we may have a problem, but in the long run, the market will be the best mechanism to sort everything out. Present goods are valued by the market anyway, and future ones will be valued by option contracts, as soon as their scarcity becomes evident to the participants *(Groenewegen* after *Meade)*.

However, this thinking has at least four flaws that prevent the market system as it works currently from being sustainable: the way of discounting future revenues, the treatment of free goods, the fact that information changes over time and the competitive mechanism that inherently prohibits cooperation.

4.2.1 Discounting

The alternative use of capital is the core component of discounting factors. As a World Bank official said (quoted by *Fields*), it would be better to put money into an account and to compensate future victims of a pollution with the yield instead of spending this amount today for abatement, if the costs were higher than the discounted damage. However, this implies that until that point in time the economic system always would bear on average the same amount of interest, which means that the efficiency of capital does not decline. However, considering the seriousness of the problems we face, this is very doubtful: what value has a car manufacturing plant, if there is no oil left, and what is the value of a town that became uninhabitable due to whatever kind of pollution?

Discounting factors, as we use them for business decision making, but also for cost benefit-analysis in welfare related decisions, basically contain four elements. The first is inflation, which can be considered as a technical one and is usually eliminated by working with real values. The second is the psychological valuation of present compared to future revenues, as mentioned in section 4.1.2 - a procedure that was already there identified as irrational. Present financial theories (compare modern portfolio theory, e. g. in *Samuels et al.*) therefore only have two factors left: the yield of alternative use of capital and the uncertainty of the financial market (not of an individual project).

The uncertainty provision inherently prohibits a long term view, since the future is by definition unknown. In section 3.3.2, I demonstrated the impact of a delay in decision making, which may be caused by uncertainty, on the sustainable use of a resource. By including uncertainty provisions in the decision making process we hide a delay factor in our management tools, instead of isolating it and trying to manage the uncertainty explicitly.

One way to solve this problem might be to impose an uncertainty provision on the yield of capital as well, which we would have to deduct from our discounting rates. Considering a possible upheaval in economic systems due to increasing conflicts, rising sea levels, climatic changes and similar threats, then it might even be possible to end up with a negative discounting rate for environmental investments. The results for decision making surely would be very surprising.

4.2.2 Treatment of Free Goods

Goods which are not yet scarce are not valued by the market and are thereby free. The economic mainstream assumes that, as soon as a good is expected to become scarce, it either gets occupied and traded by individuals, as this was the case with land in ancient times, or it becomes a public good. Then it is the task of a government to regulate the use, as it is the case for roads, for knowledge or for waste disposal. The government either can provide the public goods free for everybody’s use or put some kind of tax on it to internalise the costs that otherwise have to be carried by society.

This idea works quite well as long as the decision of use for a good and the evidence of scarcity appear within the same time. It fails, however, if a decision made on the use of a good which is free today causes irreversible damage on its availability in a distant future, that cannot surely be predicted today. An example we find in the phenomenon of acid rain: levies or control measures that may prevent further damage today cannot reverse the acidification of forest soil that is caused by emissions produced years ago.

The ‘polluter pays’ principle - a variety of the general liability regulations - can solve this problem to some extent, as it puts at least a threat of future costs to every emission. The core of the idea is that the default setting is changed: basically we have to assume that somebody might have a stake on every good, instead of assuming that every good free of charge remains a free good, as long as nobody expouses claims on it. However, as in the case of acid rain, after the event it is impossible to measure the liability of an individual polluter, and some of them even may not exist any more. Most important, however, is the fact that due to a lack of knowledge of ‘what will turn out to have caused damage’, the threat of liability becomes heavily discounted, so that it does not really lead to an avoidance.

In this context it is also necessary to mention the risk asymmetry that is inherent to our corporate laws: a stockholder of a company is allowed to reap the yield of a risky enterprise if it turns out to be positive. If it does not, because, for example, it generates more negative than positive effects for society in the long run, the enterprise may go bankrupt and the burden is shifted to the community. Therefore, the riskier a project is, the bigger is the probability that some burden is externalised. This provides thus a financial incentive to undertake such enterprises.

4.2.3 Information Changes Over Time

The efficiency of markets depends on full information to every participant - a quite unrealistic assumption. Figure 11 sketches the ‘cobweb theorem’, which is the underlying structure of many cyclic patterns in economy. It shows a supply and demand curve, and of course we expect the market being in the equilibrium. Under certain conditions, however, this may never be achieved. If for example the demand is very inelastic and reacts instantly to small volume changes with big price changes (as this is typical for food markets), and if on the other hand the supply is very elastic, but needs some time to adjust capacity (let us say, it is a food industry), the path indicated by the arrows might reflect what happens: a small shortage immediately causes increased price. This induces capacity to increase, which all of a sudden increases supply after some time. The price drops, suppliers - now facing a new signal from the market - cut capacity, and after an additional delay we suddenly have an even shorter supply than before. The price will raise dramatically, now starting the same cycle with increased amplitude. Of course, the problem could be softened if the suppliers would talk to each other and to the customers as well. Then they could adjust their investment to sound levels, instead of causing - unwillingly and acting completely rationally - the market to break down.

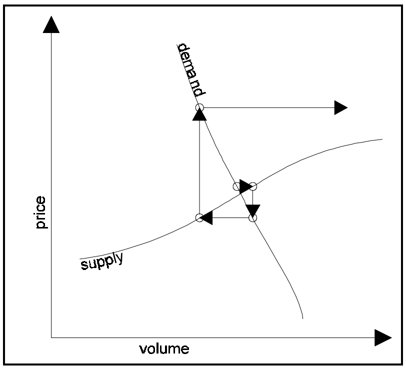

Figure 11: Cobweb Theorem

What here looks like an academical exercise, was observed as the ‘pig cycle’ in the pork market over many decades. The current food floods in Europe and the breakdown of indigenous agricultural systems in many developing countries may be other outcomes of similar mechanisms. But not only separated markets, even the economy as a whole shows these cycles, and the over-investment hypothesis (*Beardshaw* after *Hayek and Mises*) follows the same pattern of argument as given above. It depends then only on the specific properties of the systems whether the cycles remain contained near an equilibrium or exceed sound limits.

The lesson for environmental management is not only that there is a problem in economic theory, which may cause us not to see the danger of a catastrophe built into the system, but also how to overcome it: the market is not the only, and may be not even the most efficient arena for communication. If we recall the need for cooperation from 3.3.3 and the way how to overcome a prisoner’s dilemma, we know that we need to communicate in another way. Exchange of information and future plans with customers, suppliers and even competitors (chain management) can reduce uncertainty and reduce the risk of being hit by a sudden revelation of developments that are going on elsewhere.

4.2.4 Competition Prohibits Cooperation

As we saw already in the models of 3.3.3, the sustainable use of a common resource requires cooperation. However, uncontrolled competition punishes cooperation in a protected market, although in an open market a cooperating cluster could gain advantage against non cooperating actors. However, the dynamics of self-amplification, that gives further success to the successful party, provide an incentive for stronger parties to strive for a monopolistic position in the long term instead of cooperating with others (as shown in Figure 10 in 3.3.3). This, however, usually implies the over-utilisation of resources, because keeping to the sustainable limit, even if this is known, allows other parties to gain advantage. Finally, so a common notion, we might end up with the ‘good’ parties loosing and the ‘bad’ ones winning - a situation that does not provide sustainability either.

The paradox sketched here applies clearly to international trade, where existing differences in economic power are continuously amplified, encouraging the formation of the trade blocks we know now - with the poorer countries loosing. The richer countries cannot reduce their resource use, even if they would like to, because then they would loose economic power to acquire at least the resources they needed for subsistence (see also *Daly*).

4.3 Technology Will Solve It

Another optimistic view, sometimes combined with the reliance on markets, is the notion that when the time arrives that problems become serious, somebody will find a nice technical solution to meet the needs of the future again. They often quote the example of other technological shifts in ancient history, like the one from hunting and gathering to agriculture, or the development of modern infrastructure when towns grew bigger.

However, the supporters of this arguments do not take into account that our cultural pattern today is the result of an evolutionary process, and some cultures that did not happen to have the right technology at the right time just disappeared. Our present situation, however, is different: we share now global problems, so, if we do not happen accidentally to possess the right technology in time, the human species may disappear - and then there is no other culture to fill this gap.

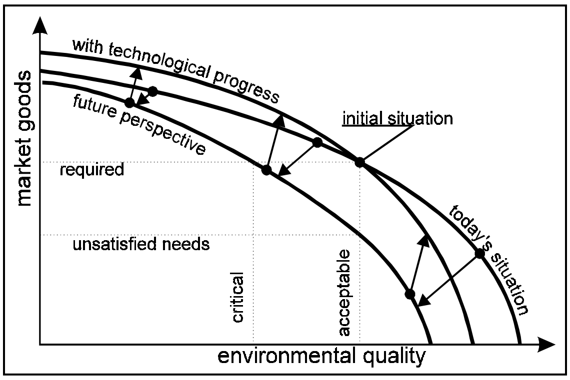

Figure 12: Production possibility curve (after Field)

I do not want to say that technology has no contribution to soften the situation at all. In the long term, I even believe that technology may be able to gradually shift the effect of environmental limits. This can be explained in a model given by *Field*, which is shown if Figure 12. He draws a production possibility curve, that shows a trade-off between environmental quality and the fulfilment of needs by producing market goods. When environmental damage shifts this line to the bottom left, future generations have either a restricted possibility to fulfil their own needs or are forced to do this with unacceptable environmental impacts. Technology may shift the production possibility curve to the upper right, allowing future generations a fair share again. This does not imply, of course, that technology will restore the original, undamaged situation. It means only that the ability to fulfil the needs of future generations is still guaranteed - presumably in other ways than those we use now - without forcing them into environmental bankruptcy.

However, the situation as we face it today is an overheated growth with the expectation of a breakdown - both patterns that show rapid and turbulent change. Technology, however, even in today’s times of ever faster development cycles, takes some time from the recognition of a problem to the solution, which adds to the delay that is already caused by the time needed to recognise what exactly is the problem at all. In addition, research to develop technology is very resource demanding. The allocation of resources, however, is subjected to market mechanisms, that will, as shown above, not provide the right incentives to develop the necessary technology until it is quite late - maybe too late.

The essence therefore is, that technology may offer some chance, but it is doubtful, whether under present conditions the pace and the direction are appropriate in the light of the expected severe problems. A possible way to tackle this may be to shift the burden of proof and the resource responsibility for the necessary research to the participants of our economy (like power generating or oil mining companies) that want to rely on technology tomorrow to offset their environmental damage today.

4.4 The Fatalist View

'Never touch a running system!' was an advice I once received from a computer specialist, when, after long efforts, we succeeded to operate a communication line which included a number of sophisticated components. The amazing realisation for me was, that, although every detail of a computer system was deliberately designed by man, the whole system itself becomes too complex to be understood, so that every thoughtless intervention would cause unpredictable, maybe serious, damage.

If this is the case for systems with known, because man-made components, many ecologists argue that it must be true even more for ecosystems, where we are far more ignorant of the consequences of our actions. Their conclusion is that we must not allow ourselves to touch natural ecosystems at all - an opinion that is understandable from their one-sided point of view.

Unfortunately, however, we have a similar conception on 'the other side': some economists, called the *Chicago School* (based on the ideas of *Friedmann*, see also at *Groenewegen*), accept the flaws in the economic system as they are described in 4.2, but state that nevertheless any governmental or other external influence would only make things worse, because nobody would be able to completely understand all the consequences of an intervention.

Considering both views together, we end up with two uncontrollable systems, where mankind takes part in both and depends on both, that run towards each other and can be expected to collide within a foreseeable time. To consider this as an unavoidable situation is the core of the Malthusian view (see *Hardin* or *Fisher)*, but with the exception that this time the whole of mankind may end up in being the loosing group.

To solve this conundrum, we have to accept that we have to manage both our ecosystem and our economic system in a coherent and compatible way. Maybe, due to the ever-present lack of knowledge, we make mistake in both, that might not be optimal for each system individually, but this is still better for the whole. But to believe in the fatalist view is a self-fulfilling prophecy: if we don't believe that the situation can be changed, we don't try it, hence it will not be changed (by the way, this is the mode in which neo-classical economic theory was confirmed).

There are many signs around that we might be able to prevent at least a total collapse: environmental awareness in many parts of the population is growing rapidly, and this allows (or forces) industry to adapt their behaviour. In the last two or three years, there was a change in public attitude towards environmental issues, which now are no longer the playground of marginal groups, but integrated parts of mainstream political thinking and sound business practice.

Of course, on a global level, developing countries cause much additional concern. However, their situation is to a large extent caused by the boundaries imposed on them by the international economic system. Therefore, fair trade is a necessary precondition for sustainable development.

5. PROPOSALS FOR IMPROVED THINKING TOOLS

5.1 Life Cycle of an Environmental Problem

Figure 13 sketches a generic framework to describe the systemic relationship of issues, as they form an environmental problem for a company. It tries to show briefly the links between an activity, causing an environmental problem, and the possible consequences from the viewpoint of a company. I have used it several times with managers, and it proved to be quite effective in explaining the occurrence of delays and distorted information.

The initial cause for the final problem is some kind of economical or technical activity, as every industrial process, but also the final product, may be. This activity has an impact on the environment, which may at some point in time be perceived by any part of society. This again may induce pressure on the causing actor to stop or reduce the activity, but also on government to create legal tools to regulate the problem. On the left hand side, we see different feedback mechanisms, that refer to some of the most common approaches of companies in dealing with environmental issues.

All these issues in isolation, of course, are familiar to everybody involved in environmental management. The point of the systemic view is to draw a larger picture. As indicated by the italic remarks printed between the boxes in the chart, from one stage to the next there are time delays, selections and misinterpretations of the issues, that together form some kind of collective perceptive distortion.

As we could see in section 3.3.2, a system is the easier to keep in control, the more immediate and the more precise the guiding information is that is used as a feedback to correct deviations from the intended stage. If only distorted or delayed signals are available, the process, which has its own, inherent inertia, may overshoot, oscillate, break down or explode.

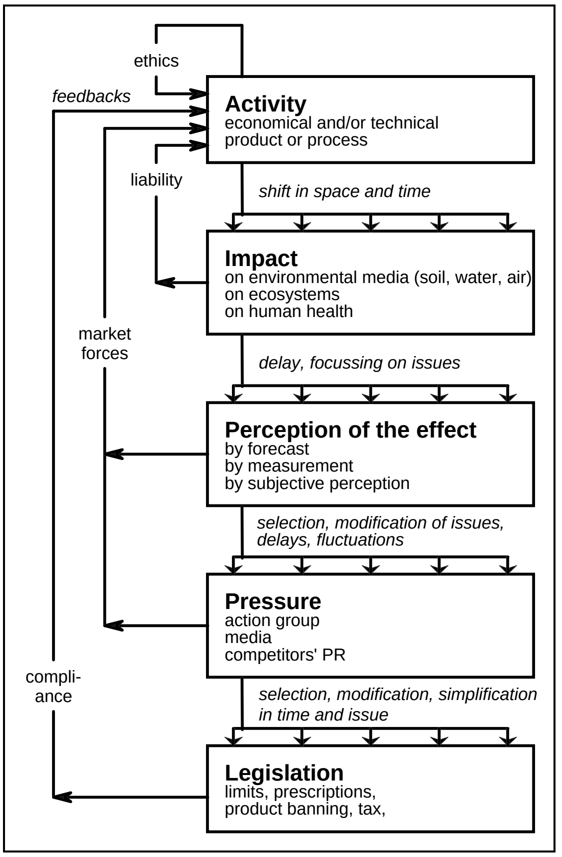

Figure 13:
Systemic structure of an environmental problem

What is the impact of this insight for environmental management? Today, most companies still consider environmental problems as marginal issues that cause only cost, but no benefits for themselves. Therefore, they want to delay expenses as long as possible. They do this by selecting the most delayed and distorted feedback channel available: compliance to legal requirement.

However, analysing situations where companies suffered severely from the repulsion of the environmental damage they caused, we often can find the pattern predicted in 3.3.2. There are many cases known were companies continued pollution of their site, until the cleanup costs exceeded their net assets and drove them into bankruptcy. Very often an investment of a fraction of that would have been enough to prevent the damage - if there would have been an information channel to induce that early enough.

An example for oscillating (or sometimes irregular, called chaotic) behaviour is the application of end-of-pipe-technology. Since legislation usually follows a piecemeal approach and has to simplify regulations for practicability (which leads in some cases to insufficient regulations, in others to unnecessary costs), such a technology only tackles a part of a whole problem. During the time of the legislative procedure and the construction of the filter, other problems may be found, so that legal requirements may already be in the process of being amended. When (just for example) a filter is operating, it shifts a burden from the air to the soil, because dust now has to be deposited in a landfill. It is not unknown, that finally toxic ingredients may end up in the groundwater, causing cleaning costs for tap water. The pattern we can see is an oscillation around the optimum solution, which causes many expensive efforts, but never reaches the goal. Actually, these costs may continue after the breakdown of the process, will say after a product is withdrawn or a company closed down.

What can a manager do to avoid such unnecessary efforts? Figure 13 shows information channels that rely on more direct and precise feedback. In the past, many companies switched from compliance to reactive, market driven behaviour: it was either the consumer, who could realise a problem himself, or pressure by media, environmental activists or even the competitors' better image that induced companies to react after a problem received publicity.

In these days, an even shorter feedback loop is driven by the fear against liability - caused by some large bankruptcies. This fear is now even causing potential polluters to examine actively the potential impact of their activities on the environment.

The shortest feedback, however, is indicated at the top left corner of the activity-box: if an environmental ethic attaches intrinsic value to natural goods, any impact will be avoided at all whenever possible. In most cases, it is then even not necessary to direct effort to monitor potential effects, and all resources can be directed towards a minimisation.

Of course, the structure as outlined here is a rough simplification of a very complex web of issues. In reality, every industry and every company is facing a different situation, but the framework given here may be useful as a starting point to examine the 'bigger picture' in the individual case.

5.2 Environmentally Benign Behaviour as Self Interest

There are many projects and examples around (e.g. *SPURT, UNEP*), which prove that environmentally sound behaviour may even pay off in immediate financial terms. However, with this argument it is easy to insult managers: they believe that where there was a cost saving potential, they would have realised that already before considering environmental issues. On the other hand, it is likewise possible to find many projects that did not pay off. The examples are therefore quite suitable to inspire the creativity of committed people, but not to cause reluctant ones to change sides.

I think, although small operational savings are a good start for a company, much bigger advantages may lie in strategic positions. As the CEO of a famous multinational company once pointed out, '*In the long run, no company can exist against the society within which it operates*'. The consequence is that in the long run all external environmental costs will become internalised in some way, be it by law, by market boycotts, by the restriction imposed to suppliers, by unmotivated workforce, by liability payments, by increased cost of waste disposal or any other mechanism. A company that considers these future expectations in its long term decision making, will more easily be able to convert the threat of environmental issues to a competitive advantage. Finally, the individual goal becomes identical with societies goal - and that is what cooperation is about.

5.3 The Second Law of Thermodynamics: Prevention is Better

The second law of thermodynamics is a basic physical concept that underlies all processes in nature where different substances are involved. Roughly spoken, it says that by nature materials tend to mix up if they are not prevented to do so, thus entering a stage of lower value. An attached measurement of 'disorder', called entropy, is increased. The same is possible for energy, like thermal energy: bodies with different temperature exchange heat until they are equally warm, comparable to water in connected basins, that equals out the surface level. According to the first law of thermodynamics, energy cannot be destroyed, only converted. However, to use energy, it is necessary to have a flow of heat from a higher temperature to a lower level, just like water can only drive a wheel if it is allowed to flow off at the bottom.

To describe these relationships in a scientific way, physicists have created the dimension of *entropy*, which is a measure of 'disorder'. In a closed system (where neither energy nor substance is exchanged with the surroundings), so the physicists language, entropy can only increase, never decrease. The important conclusion of the second law of thermodynamics is that, within a closed system, order - the higher stage of material that forms things like a biological body, a machine or a consumer product - can only be generated (or entropy reduced) by sacrificing a greater amount of order (producing more entropy) in other parts of the system. This means, to recover material from ore or from contaminated waste (which both are low ordered stages) needs generally more (usable) energy than the amount that may have been saved by allowing the waste to degrade.

Although in many cases a quantitative assessment of the 2nd law of thermodynamics is not feasible, the qualitative lesson - that every mixing of materials tends to degrade its value and requires efforts to be reverted - underlies the concept of ‘Clean Technology’. In this way, the argument of opponents to the classic environmental technology (end-of-pipe-technology) has been confirmed: healing a damage after it is occurred often requires inordinate efforts. In many cases, this is reflected in financial calculations as well.

Another argument that opponents of environmental protection used in the past, was that, due to the second law of thermodynamics, sustainability would not be possible by definition. However, the earth is not a closed system: we receive every day $1,5 * 10^{22}$ J of radiation from the sun, which - like a big waterwheel - drives the ecological system and keeps all its material flow going. In this sense, the opponents are right: the sun is doomed to extinguish one day, but this will be in some billions of years. To see that, mankind will first have to solve some other problems.

In contrast to the biosphere, the technosphere nowadays relies mainly on the consumption of $1,0 * 10^{18}$ J/day (a factor of 15 000 less than solar radiation provides) from accumulated, fossil energy. This seems to be like a miller who would use a lake that is only filled by a small river: when the lake is exhausted, his mill (the capital) has no value any more. All this flow is used to support the existence of $5 * 10^{9}$ human beings (actually only 20 % of them), who would need only $6 * 10^{16}$ J (the 250 000th part of sunshine energy) for their biological needs. If we consider everything else as conversion inefficiency, the real limits seem not to lie in this area.

5.4 The Challenge: Measurements for Sustainability

If we want to manage sustainability, we need a set of management tools that enable us to appraise performance, to set targets, to assess progress and to compare different options for decision making.

The easiest way to do that is to use physical quantities, like volume of waste, weight of materials or energy units. A great number of problems in the first instance can be handled with such measures, so they will be used heavily in the management systems that are going to be installed now in many companies. Moreover, physical measures allow some benchmarking within industries, although at the moment it is very difficult to obtain the required information, because it relates to sensitive process information.

The issue, however, becomes more complicated when it comes to compare the famous ‘apples with the oranges’, as it is the case in life cycle analysis or in the decision to be made between different process technologies available for a new investment. Basically, we have three approaches: political scores, scientific scores and monetarisation.

Political scores try to identify a valuation of environmental goods that is already present in society (like the *Swiss Ecopoint Method* from *Müller-Wenk*) or is achieved by a procedure of consensus building (see for example *Heijungs* or *Lindeijer*).

Scientific scoring systems try to aggregate similar impacts of different pollutants. Examples are toxicity equivalents (like the ones for Dioxins), the CO_2-equivalent for greenhouse gases or the ‘NOEL’ (no observable effect level) for impact on ecosystems. These systems do a good job within homogenous classes of pollutants, although they still are far away from being indisputable. The aggregation between classes is much more difficult. There are some approaches in discussion that are based on the second law of thermodynamics (e.g. *Finnveden*'s '*exergy*' concept); however, to derive practicable systems from them seems to be very difficult.

The third way to aggregate environmental data is to put monetary values on them. The approaches are different, but a commonly accepted one is based on cost-benefit-analysis (compare *Field*) and willingness-to-pay examinations. Another possibility is to assign the cost of remedial measures to a pollution. If we recall for example Figure 12, the investment in technology necessary to provide unaffected fulfilment of needs to future generations could be a reasonable measure. If the burden of proof lies with the polluter, this has two positive side effects: first, the polluter has an incentive to develop a technology that offsets the effect of his activities, and second, the uncertainty problem works against pollution, not against the environment.

6. INSTEAD OF A CONCLUSION

Since this report was not intended to dig deeply into an isolated issue, but to indicate the existence of a broader picture, it would be audacious to draw a conclusion at the end. Mental models are something that cannot be imposed on somebody - every individual decides freely to accept or to reject them. Models can only be offered, and the best an author or a teacher can do is to make them as plausible as possible and to attach them to perceptions already present in the audience's mind.

Since I had the general manager as target group in mind, I hope that the use of financially based models was an appropriate means to do so. I am sure that in this area much more could be done, but maybe the thinking above provides some starting point. If we can succeed in developing this way of working with managers, we hopefully can make it easier for them to make the leap from accepting that there is some kind of an environmental problem to the use of heuristic and ethical concepts that cause them to behave environmentally benignly, even under conditions of uncertainty. And finally, we should not forget that to support a decision against one's own doubts and external attacks, some rationalisation is necessary, that moral concepts alone cannot achieve.

If there is a final inference to be made, I think it can be the following:

Our traditional thinking focuses on details, thereby neglecting the bigger context of a picture. Like every goal that is neglected, the bigger ('integrated') issues fell back - even more the more perfect the small scale goals were achieved in a belief that many small optimal decisions would add up to the big optimum. As the examples on competition and economic systems showed, this is not always the case. If we agree thus that to reach the goal of global sustainability, we need integrated system thinking as a 'Critical Success Factor', this implies that two other success factors have to sacrifice some of their exclusivity - two thinking principle that rely on the notion of small optima adding up to big ones: the free market and democracy. Like with the holy cows in India, I do not think that we have to slaughter these principles, because for most of the limited and local issues they have proven to be very valuable in the past. However, we might think about domestifying them, to get the best use out of them. If they become means, not ends in themselves, it will be easier to decide about necessary steps that are required to achieve the highest benefits for society.

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I gratefully thank Prof. Huisingh for accepting this unconventional topic for a coursework report. I am aware of the fact that the approach used is somewhat different from common academic style. However, I believe to achieve progress in environmental issues we have sometimes - at least for some moments - to leave established paths.

I thank Mr. Christopher Russell for his proposals on stylistic and grammatical improvements.