Sustainable resource use. An enquiry into modelling and planning.
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V. Modelling for adaptive planning: summary and conclusion

In the previous four chapters I have reviewed several approaches to resource planning, reflecting my own development in modelling. The first model of Chapter II, on exploitation of Western Europe's oil and gas, was deterministic and rigid. It was also explicitly instrumental in policy issues and has been used as a provocative forecast, not as a mechanistic prediction. The second model, on optimal resource depletion, adds the element of formal valuation of future developments. Here, too, the dynamics of the model is deterministic. Once the planning context is set and resource economic data on e.g. demand elasticity and marginal cost are accepted, the initial state governs the trajectory throughout the planning period. It was concluded, that this approach is not to be used for forecasting but may provide some meaningful indicators.

The electric power supply model of paragraph IV.1 was, like the oil and gas model, meant to be instrumental to policy issues, but with more explicit demarcation of formal algorithms and decision context. Alongside with model extensions, the construction of 'scripts' for the future, or scenario's, has been put forward. One aspect, then, is the ability to know: 'strongness'. The simulation model should be used explicitly as a relatively strong tool in a relatively weak planning environment. Another aspect in the construction of model-based scenario's is the ability to plan: 'hardness'. While modelling complex socio-economic systems, one should thoroughly assess the degree to which parts of the system are thought to be amenable to planning.

These considerations have led to the construction of the simulation game of paragraph IV.3. The nature of model relations and parameters is explicitly taken into account as e.g. in the distinction between system parameters, scenario variables and decision variables. The simulation is interactive, forcing the decision-maker to respond to past action and allowing him to learn about the system's behaviour. It was concluded that this approach provides an adequate tool to learn the "art" of adaptive planning.

I suggest the following conclusions. Both part A and part B of this dissertation indicate, that there are inherent limitations to long-term predictability of even simple real-world resource systems. The corresponding image of the future is one of both design and adaptation, of contingency within constraints. Long-term forecasting is at best a script, a "Gedanken"-experiment. The ability to respond adequately to change is crucial. The rolling ball in a landscape may be an adequate metaphor - but including real-world irreversible interaction and in a landscape full of surprise, discontinuity and change.

Yet, mankind is faced with an increasing need to "manage" parts of the future. Due to longer lead-times of e.g. technological constructions and increasing interaction - both in size and diversity - with the slow dynamics of the biosphere, there is a need for more accurate and longer-term planning. This is reflected in the very quest for sustainable development. This need for more planning is thwarted by the inherent limits to exploring and predicting the real-world - including our own actions - for more than a few years ahead.

This introduces a paradox. In metaphorical language, one could express it this way. We are travelling in a landscape with a map of the surroundings. Gradually, we explore larger parts of the land and improve the maps and the mapping techniques. This itself spurs the exploration and more and more distant areas are mapped - some of them found to be full of precipitous cliffs, narrow passes and unexpected valleys. Travelling around, slow but distinct changes in the landscape are discovered and these dynamics are incorporated in the maps. As our actions spread and intensify, we start to recognize that our own actions change the landscape, too. Maps can no longer be used without taking into account how we go next. Still better tools are needed: more accurate because of the landscape's complexity, farther into the future because of increasing travelling speed. For some parts such tools seem to be available. In other areas, it seems they are impossible. This metaphorical description of the human adventure calls in itself for caution and humbleness. Keeping this in mind, some guidelines can be given.

An appropriate paradigm to construct and policy exercises are proposed, formal encodings of parts of the over-all model. The same holds for developments. Endogenous scenarios and consensus behaviour. Information is interactive change.

The decision context (or environment) scenario's. Because of the perception of underlying socio-economic development. They should be given a particular framework of action.

This leads us back to the first starting point, in the context of man's increasing need to "manage" parts of the future. Exponential growth of population and economic output are again reflected in a particular world-view.

Our models of the world, the landscape, which balance may be lost and the map which is hold by so many other people germinate images and tools to cope with a balanced and sustainable future.
An appropriate paradigm to explore sustainable development is adaptive planning. Simulation games and policy exercises are proper devices to learn and communicate. In this perspective, models as formal encodings of parts of the real world, should support a weak and soft decision environment with strong and hard tools to assess options for the future.

Observables and their encodings (variables, parameters) should first be ranked - or at least discussed - according to their perceived strength and hardness, to assess their place in the over-all model. The same holds for the inclusion of facts and assumptions on future options and developments. Endogenous optimization techniques should preferably be used for relatively rigid consensus behaviour. Informational and expectational feedback loops should be opened up for interactive change.

The decision context (or environment) should be made as explicit as possible e.g. in the form of scenario's. Because of the weakness of underlying mental maps and the diversity of the perception of underlying softness, formal encodings are mostly inadequate to explore and communicate the vast richness of the decision context. Metaphors can be very helpful for this purpose. They should be given a more prominent place in complement to simulation modelling in the over-all framework of adaptive planning.

This leads us back to the first two chapters of this dissertation. It puts resource planning again in the context of man's image of future reality and of human values. So-called "laws" like exponential growth of population and capital or a constant ratio between resource use and economic output are again recognized for what they are: metaphysical propositions in support of a particular world-view.

Our models of the world, the equivalents of Perseus' shield to face Medusa, mirror a future in which balance may be lost and which no longer sustains mankind in the rich and equitable way which is hold by so many of us as a promise to our posterity. The great challenge ahead is to germinate images and tools which can lead the Earth and, with her, mankind towards a more balanced and sustainable future.
Summary Part A

The concept of "Sustainable Development" has been proposed in the last decade as a guiding principle for more responsible management of the earth. In a first exploration I present in Chapter II four underlying ingredients: the image of the future, the end-means spectrum, knowledge and tools. In the context of this meta-structure I indicate five perspectives from which the concept of "Sustainable Development" can be formulated: the Technocrat-Adventurer, The Manager-Engineer, the Steward, Partners and the "cultural" orientation.

A model can be looked upon as an encoding of part of reality. Many resource dynamics models are analogous or isomorphic with natural science encodings. In Chapter IV I illustrate this with some simple ecological and economic models - and their differences. "Sustainability" is discussed in the context of stationary state. In Chapter V some recent developments are indicated: optimal depletion models, changing structural parameters, non-linear models. The increasing complexity of these encodings are a less excessive idealisation of the real world - and an invitation to humbleness as well. A further refinement of the concept of "Sustainable Development" is given from the emerging perspective of limited falsifiability and predictability.

In Chapter V I distinguish between "Sustainable Development" as Declaration, with ethical value as guiding principle, and as Definition, rooted in scientific models. The latter presents two possible definitions of "Sustainable Development" related to economic and ecological science: as growth-with-constraints and as part-of-the-whole. For both some model-based indicators are given.

Summary Part B

Forward calculations of energy supply, as for depletion of Western Europe's oil and gas reserves, can be presented as "mechanistic" predictions or provocative alternative future. Looking back, in Chapter II.2, shows how much the pretense of prediction would have been falsified. More complex, normative forward calculations, as for optimal depletion patterns for mineral resources, are one step further removed from "mechanistic" predictions - despite the analogy of such models with simple mechanical systems. They are also one step closer to planning - and, consequently, to valuation, as is briefly discussed in Chapter III.2.

Facts and values are mixed up in planning. To some extent this has been made explicit in a simulation model of the electricity supply system, which has been developed at IVEM. As is discussed in Chapter IV.2, the goal has been to use a relatively "strong" and "hard" model in a "weak" context. The resulting concept of interactive policy exercises is illustrated with a simulation"game" on electric power planning. It is concluded that - given the increasing complexity of resource systems and at the same time increasing need for planning - adaptive planning in a framework of explicit metaphors provides the best perspective.