New Approaches to Soft Anticipatory Design for Spatial Decision Support Systems

Anita Håkansson
Viveca Asproth

ITM / Informatics, Mid Sweden University
SE-831 25 ÖSTERSUND, Sweden
Fax: +46 63 165505
E-mail: anita.hakansson@itk.mh.se, Web: http://www.itk.mh.se/~anihak
E-mail: viveca.asproth@itk.mh.se, Web: http://www.itk.mh.se/~vivasp

Abstract
The human management of geographical space is far from perfect. Factors that aggravate the situation may be found in the planning and decision support systems applied for managing decisions and actions concerning geographical space. A majority of those support systems are based on the reactive paradigm (Rosen, 1985) and the classical two-valued logic of an abstracted and idealised world (Kosko, 1993). So far, modern research in anticipatory computing, fuzzy logic and soft systems design unfortunately has not, to any significant extent, been applied in geographical management systems. The purpose of the work, reported in this paper, is to present some ideas for a model for management of common regional resources, based on anticipation, soft systems design and systemic spatial modelling.

Keywords: Anticipatory Design, Geographical Space Modelling, Spatial Decision Support, Soft Computing, Multi-Modal System

1 Problem and Purpose

Geographical or physical space, seen as a three-dimensional Euclidean space, is a common space for all concrete systems (Miller, 1978). Hence, all that individuals, as well as human systems in common, do will affect that common space and everything that happens in the physical space will have an impact upon us. Consequently, a good management of our common geographical space will be of paramount importance for a sustained life on earth.

However, the human management of geographical space is far from perfect. Factors that aggravate the situation may be found in the planning and decision support systems applied for managing decisions and actions concerning geographical space. A majority of those support systems are based on the reactive paradigm (Rosen, 1985) and the classical two-valued logic of an abstracted and idealised world (Kosko, 1993). So far, modern research in anticipatory computing, fuzzy logic and soft systems design unfortunately has not, to any significant extent, been applied in geographical management systems.

Hence, the purpose of the work, reported in this paper, is to present some ideas for a model for management of common regional resources, based on anticipation, soft systems design and systemic spatial modelling.

2 Theoretical Base for the Research

A set of earlier research findings has been used to develop a model for soft anticipatory design for regional resources. Asproth and Håkansson (1987) presented a model for resource and environment policy program. Rosen (1985) has defined the base for the anticipatory paradigm. Dubois (1998, 2000) has gone further by defining incursion, hyperincursion, and weak and strong anticipation. Holmberg (1997) has defined a first tentative model for spatial anticipation and fuzzy logic, and soft computing have also been applied in a spatial context (Asproth, Holmberg, Håkansson, 2001). Schwaninger (1990) has defined a model for objectives and control variables at different logical levels of management. De Raadt (2000) has developed a design model for management of communities, based on a multi-modal systems framework.

3 Problem Domain

The main planning problem is to identify and reinforce those forces and actions, which may trig or launch a positive development in the region. Further, it is mandatory to handle natural resources in a sustainable way and to maintain a favourable environment.

Those strivings have been formalised into a Resource and Environment Policy Program (REPP) according to Figure 1. It is not possible to discuss REPP in this context, but its purpose is to facilitate the management of a region. REPP consists of four main interrelated and interdependent components:

1. Resources in the form of land, water, air, and inhabitants.
2. Resource claims, i.e. the needs and demands that different actors have on the resources.
3. Current regulations such as regional plans, area plans, guiding principles, ordinances etc.
4. The actual stand points and decisions for the present situation.

The example in this paper will not handle all resources in the REPP model just the control of water resources and the hydro electrical power plants.

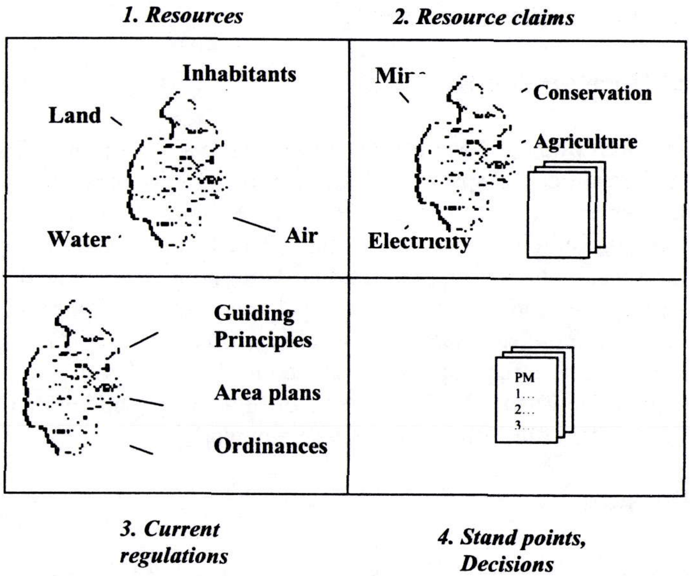

Fig. 1: Model for Resource and Environment Policy Programme.

4 Applying Schwaninger's Systemic Management"

Schwaninger (1990) identifies objectives and control variables at different logical levels of management. From the point of view of anticipation one of Schwaninger's conclusions is interesting. He states (Espejo et al, 1996) that it is not possible to control or anticipate the variables in one of the models with that model. Only models on a higher level have a good prediction or anticipatory function in relation to the model on the next lower level. Models of a higher level also sees longer into the future what will happen on the next lower level. Schwaninger has elaborated this model for management of business firms. The model is applicable at different recursive levels, for example a business unit, a subsidiary company and the corporation.

Management of common regional resources is an issue at the society level. The example in this paper, control and management of water resources for hydro electrical power can be seen as something in between the organisation and the society level as it is a corporation that handles the management and control, but has a responsibility at the society level. To see weather Schwaninger's model is applicable at this system level we have identified some norms for our case (see figure 3).

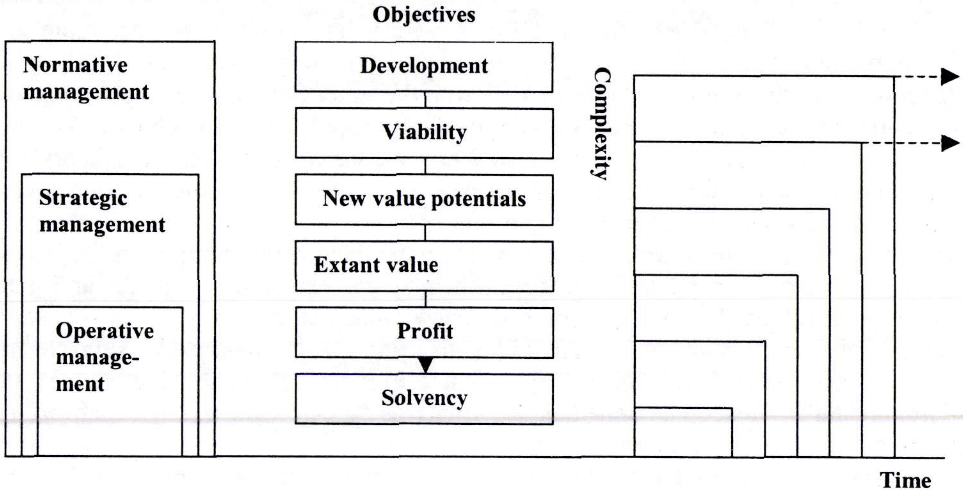

Fig. 2: Objectives at different logical levels of management (Schwaninger 1990)

At the operative management level, the norm for the solvency objective is to get the best price at the moment for the electric power produced. To maximise the profit, regulation aims to keep as much water in the reservoirs as possible and use it when prices are good. Within the water system several constraints and restrictions can be found. The

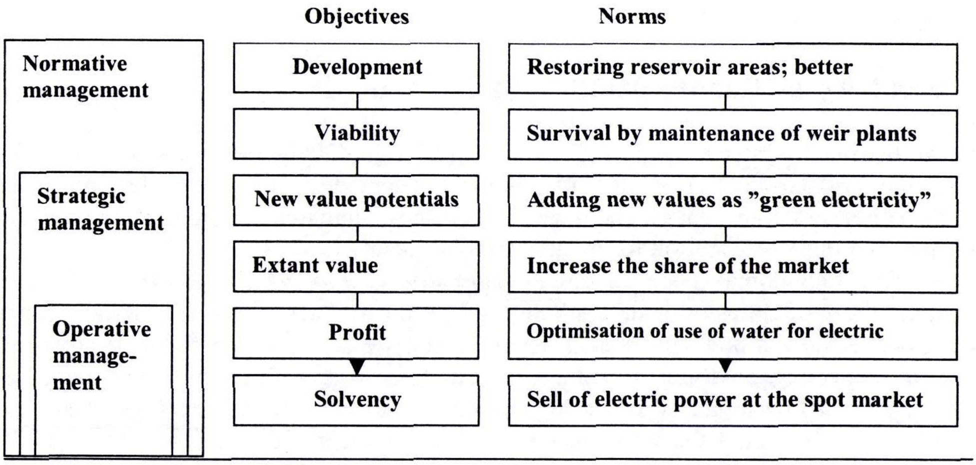

Fig. 3: Example of norms for different management levels and objective

water levels in lakes (reservoirs) and rivers have to stay within the maximum and minimum limit at all times. Prizes on electrical energy vary over time. Further, the efficiency of electrical power stations varies with the water flow through the station, and each station has a maximum production limit. Water supply varies much over the year, but also between years. In (Asproth et al, 2001) we tested to use an anticipatory soft computing approach for control and management of water resources and hydro electrical power stations with promising results.

A norm for the objective extent value potentials at the strategic management level is to increase the market shares with help of for example low prices and good custom relationships. To obtain the objective new value potentials, the norm is to solve customer problems. Many people of today feel some ambivalence in using electric power as there is a need for energy saving. Electric companies that reduce the environmental influence can sell their electricity as "green" and through that reach a custom group with specific needs.

Survival in the long run is the goal at the normative management level. The first objective here is viability and an example of a norm is to maintain dams, weir plants and hydro electrical power plants. Viability, understood by Beer (1979), is the ability to maintain a separate existence. From a systemic point of view, the organisation should aim at viability beyond survival. Ackoff (1994) defines development as a system's growing ability and desire to fulfil its own and others' needs. According to Schwaninger (Espejo et al, 1996), social, political, cultural and ecological aspects have to be considered, given space to ethical and aesthetic concerns for the pursuit of ideals. Examples of norms for the development objective is to use more efficient technology that is energy saving or helps to produce more electricity, restore reservoirs by improving fishing possibilities and improving the aesthetic impression of the reservoirs and their surroundings.

5 Applying de Raadt's Multi-Modal System

In Multi-Modal Systems Method (MMSM), de Raadt (2000) describes four domains and their modalities, necessary to take into consideration when designing the organisation of a community. The question is if these domains and modalities are valid when designing a corporation for management at society level?

The four domains are ***character***, ***community***, ***intellect*** and ***nature***. *Character* contains the modalities ethical, aesthetic and juridical. According to de Raadt, ethics demands self-denial and sacrifice, it demands that we give up something of ourselves without expecting anything in return. In addition to sacrifice, this ethic demands courage, for acting ethically has a high price. In our case **ethics (caring)** means for example, not to exploit the water resource for hydro electrical power at any price. De Raadt also declare that implicit in the definition of the modalities is a communal context. A person does not exercise love, grace and justice by being a hermit, but by belonging to a community. The same reasoning can be valid for a company or an organisation, as they cannot exercise **ethics**, **arts** or **jurisprudence** without belonging to a society. **Art** is an expression of our humanity and for the example in this paper it means, among other things, to protect the water power plant surroundings. **Justice**, or jurisprudence, is something that must permeate the whole organisation.

The next domain, *community (society)*, contains the modalities operational, economic and social. De Raadt means that the character traits must be put into action within a community, and they must be transformed into a vocation or a call to work. Work is something that belongs to operational modality. Work requires resources and organising to be viable, and this is the function of management, which belongs to the economic modality. Furthermore, work and its management require a social structure. In our case the character traits are put into action within a society. **Work** is required to build and maintain a corporation, which main task is to supply the inhabitants with hydro electrical power. The **economic** modality represents of the quantity of electric current that the corporation can make available.

The third domain, *intellect* (knowledge), contains the modalities epistemic, informatory, historical and credal. The epistemic modality is, according to de Raadt, the realm of understanding, and is provided by information. Information emerges out of a historical context, and can only be made possible through faith. Faith resides in the credal modality. In our example the **epistemic** modality means understanding the ecological system to be able to manage the water in a river valley for example. **Information** can be collected from different sensors as well as from **historical** data. The **credal** modality is the corporation's trust to the information source.

The three domains, character, community and intellect, belong exclusively to man, but the fourth domain, *nature*, belongs to all creatures, including man. The fourth domain contains the modalities psychic, biotic, regulatory (cybernetic), physical, kinetic, spatial, numeric and logical. The three modalities psychic, biotic and cybernetic function as boundaries that help us separate animals, plants and machines from the rest of the physical objects in the world. The "water" from our example, gradually runs on to the oceans through rivers where it evaporates by taking energy from the sun and rises up to the atmosphere. This process needs no human intervention, and therefore it is a natural machine with a **self-regulating** mechanism, but it is not alive like a plant and does not operate in the **biotic** modality. Furthermore, water is a **physical** object that can be hold in our hands, it can be **logically** defined because we can distinguish it from another object, it occupies a certain amount of **space**, it displays a **kinetic** notion since it is moving through the river valley.

6 Integration of Systemic Management and Multi-Modal Systems

When discussing de Raadts modalities, it is obvious that the three domains *character, community and intellect* can be associated with the administration of a corporation, a company or an organisation, and the fourth domain, *nature*, can be associated with the "product". In "Living Systems" (1978), Miller describes a corresponding classification, information and matter/energy, where information correspond to *administration* and matter/energy to *product*. This means for example, that spatial problem always are connected with the product or the production, not to the administration of the organisation. But, on the other hand, spatial problem can be handled at any level in the

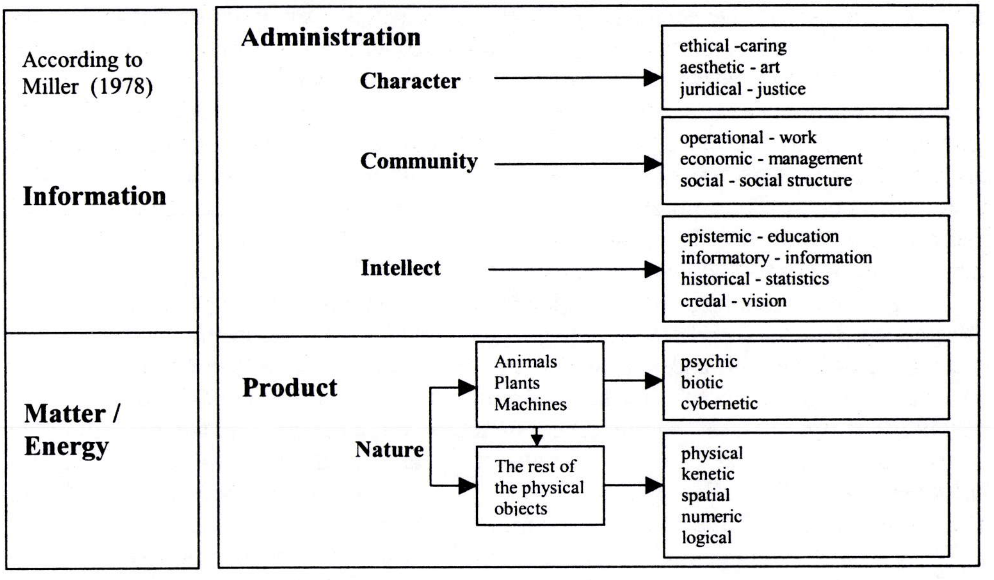

Fig. 4: De Raadts modalities in relation to Miller's grouping of subsystems

organisation, *normative, strategic and operative level* (Schwaninger 1990), because the result of a decision making can give consequences in the long term or in a short time (see figure 5, Nature). Employing people, however, is a problem connected with the administration, but as for spatial problem, they can be handled at any level described above (see figure 5, Operational, Epistemic).

When adding de Raadt's modalities to Schwaninger's model we see that ethical, aesthetic and credal modalities are found at the normative management level and especially for the development objective. The operational and economic modalities are relevant at both the operational and the strategic management level, though with differing content.

Historical, juridical, informatory, epistemic and social modalities can be applicable on all three levels and for all objectives. The modalities must however be used quite different at different management levels.

Keen and Morton (1978) have identified different characteristics of information by area of decision based on the managerial activities, strategic planning, management control and operational control. The information requirements of each of the three categories are very different (see Table 1).

Table1: Information characteristics by area of decision. (Keen and Morton, 1978)

Task Variables	Strategic Planning	Management Control	Operational Control
Accuracy	Low	↔	High
Level of detail	Aggregate	↔	Detailed
Time horizon	Future	↔	Present
Frequency of use	Infrequent	↔	Frequent
Source	External	↔	Internal
Scope of information	Wide	↔	Narrow
Type of information	Qualitative	↔	Quantitative
Age of information	Older	↔	Current

As can be seen in table 1, strategic planning has completely different requirements on information than operational control. Operational control, for example, require detailed information of high accuracy with the sight adjusted to the present or the nearest future, while strategic planning requires aggregated information with low accuracy and a time horizon stretching into the future. Management control, on the other hand, has requirements on information that varies from the requirements on information for strategic planning to the requirements on information for operational control, as the arrows in table 1 indicate.

A similar reasoning can be carried out for the other four modalities. As an example the epistemic modality can be mentioned, that is the realm of understanding and is provided by information. Understanding and education demands, besides different characteristics of information, also cognition theories and one has to use different pedagogy in education at different management levels.

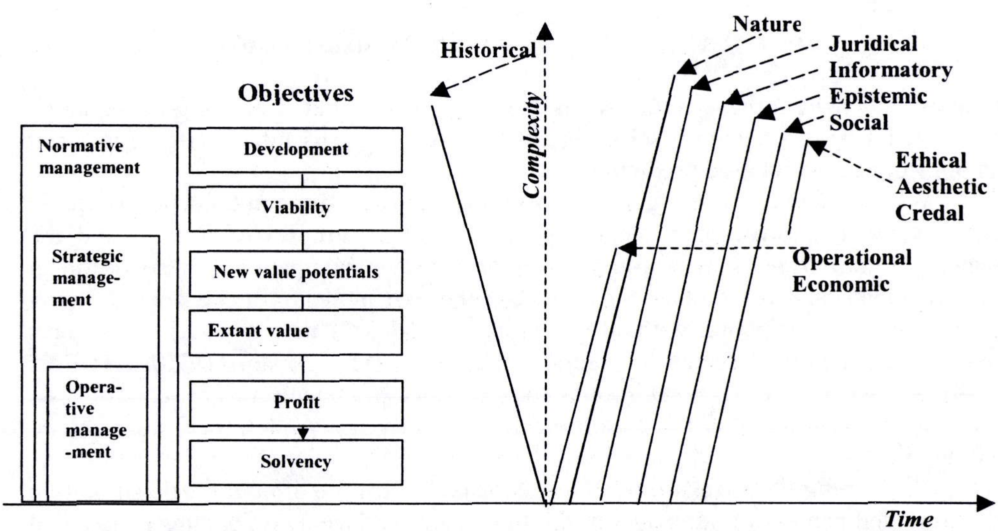

Fig. 5: Schwaninger's model with de Raadts madalities, in a time perspective

7 Anticipatory Principles versus Systemic Management and Multi-Modal Systems

Robert Rosen (1985) defines the concept of an anticipatory system as a system containing a predictive model of itself and/or of its environment which allows it to state at an instant in accord with the model's predictions pertaining to a later instant.

Dubois (2000) makes a distinction between strong and weak anticipation. A discrete weak anticipatory system computes its future states, according to equation 1, as a function of its states at past times, ..,t-2, t-1, present time t, and predicted future times, t+1, t+2,...,. In equation 1, **p** denotes a control parameter.

$$\mathbf{x}(t+1) = \mathbf{A}(\ldots, \mathbf{x}(t-2), \mathbf{x}(t-1), \mathbf{x}(t), \mathbf{x}^*(t+1), \mathbf{x}^*(t+2), \ldots, \mathbf{p}) \quad (1)$$

Here the system states at future times, i.e. $\mathbf{x}^*(t+1)$, $\mathbf{x}^*(t+2)$..., are computed in using a predictive model of the system. Hence, the effectiveness of weak anticipation very much depends on the possibility to build a good and accurate model, $\mathbf{x}^*(t+1)$, $\mathbf{x}^*(t+2)$....

Because weak anticipation requires a good and accurate predictive model of the system, the predicted future time has to be as short as possible. Therefore weak anticipation is most useful on the operative level, where the valid **time** for the predicted model is finite. When going from operative level to strategic and normative level the **complexity** increases. This fact also contributes to the stand that weak anticipation is most useful at the operative level.

A discrete strong anticipatory system computes its next state at time t+1, according to equation 2, as a function of its states at past times, ..., t-2, t-1, present time t, and even its states at future times, t+1, t+2,...,. Even here **p** denotes a control parameter.

$$\mathbf{x}(t+1) = \mathbf{A}(\ldots,\mathbf{x}(t-2, \mathbf{x}(t-1), \mathbf{x}(t), \mathbf{x}(t+1), \mathbf{x}(t+2), \ldots, \mathbf{p}) \quad (2)$$

In strong anticipation those future states at t+1, ... are computed in using the equation itself. Such a system becomes self-referential in computing its future states from itself and not from a model based prediction.

With the same reasoning as for weak anticipation, strong anticipation could be useful at the normative or strategic level, where the **complexity** is high and the predicted future **time** is a long-term question. Strong anticipation is also useful at operative level, and no comparisons between the two models will be done. Strong anticipation, or anticipation without an explicit model, is a new discovery of Dubois (2000). Superficially it seems to contradict Ashby (1958), Conant (1970), and Beer (1979) and what they have said about the necessity of models in any control task. However, if we reflect that the system itself is its own best model, there needs be no contradiction.

Concerning de Raadt's modalities, anticipation can be strongly efficient within the nature and community domains in the first place, as these two domains handle real and resolute problems with definite rules. The two other domains, character and intellect, manage more abstract problems and problems, which have no "right" answers, as many of the answers are depending on political views.

An incursion is an inclusive or implicit recursion, an extension of the recursion in the following way

$$x(t+1) = f[x(t+1),p] \tag{3}$$

where the value of the variable at each instant t+1 is a function of the value of this variable at the preceding time step t, but also at time t+1. This defines a self-referential system that is an anticipatory system of it self. (Dubois, 1998)

Dubois (1998) considers that there exists a paradox. If an anticipatory system contains a model of itself, this means that the model of itself must include also the model of itself and so on until infinity. There is no doubt that it is difficult to simulate such systems but not unable to solve.

Schwaninger on the other hand states (Espejo et al, 1996) that it is not possible to control or anticipate the variables in one of the models with that model. Only models on a higher level have a good prediction or anticipatory function in relation to the model on the next lower level. This means of course that the paradox of infinite embedded models still remains, but it is possible to look upon it as valid for every adjacent pair of management levels within a range.

Hyperincursion is an incursion with multiple solutions. The number of future values increases as a power of 2. As the system can only take one value at each step, a decision function can be added for making a choice at each time step. The decision process could be explicitly related to objectives to be reached by the state variable x of the system. The decisions do not influence the dynamics only guide the system, which creates itself the potential futures. (Dubois, 1998).

The possibility to explicitly relate to objectives in the decision process indicates a potential use at the normative management level.

Let us start out from the statement that only models on a higher management level have a good prediction or anticipatory function in relation to the model on the next lower level. For example has profit a pre-control function in relation to solvency. In our case, this means, for example, that the optimisation of use of water for electric power production over a longer period guarantees earnings and determines the solvency. At the next level 'value potentials' pre-control profit. Through increase in shares of the market, the market potential for electricity is good and thereby the profit is increased. Examples can be found for every adjacent pair of management levels. In earlier work (Asproth, Holmberg, Håkansson, 2001) we have tested different anticipatory approaches at the operational management level, but most of the work to examine which anticipatory approaches are applicable at different management levels still remains to be done.

When it comes to the highest level, development, there is no higher level yet defined and thus has no pre-control function. Schwaninger (Espejo et al, 1996) says that a fundamental prerequisite for the survival of on organisation in a changing environment is the ability to adapt to change, the essence of 'learning'. The organisation requires an organisational learning capability. Rosen (1985) conjectured that adaptation and learning systems in biological processes are anticipatory system.

8 Closing Remarks

The objective here has been to develop better means for handling complex and incomprehensible problems in geographical space. The paper presents a new approach to physical planning and management, using anticipation, soft systems design and systemic spatial modelling, resulting in new synergies and interesting combinations of design models. As we see it, anticipatory approaches mostly have been applied at the operational management level.

The next evident step in the work presented here is to examine which anticipatory approaches are applicable at different management levels and for different modalities. Another interesting question is at which level it will be most profitable for a society or an organisation to design anticipatory decision support systems? Or is the most profitable anticipatory system to find in another direction, the modalities. Further more, is it possible to build a good and accurate predictive model of a system, which is cogent when working with weak anticipation, when the world around us constantly change? Shouldn't the predictive models be good, accurate and dynamic? Working with strong anticipation the system itself is its own model, how can we assure the necessary dynamic development of the system itself, and thus the "model"?

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