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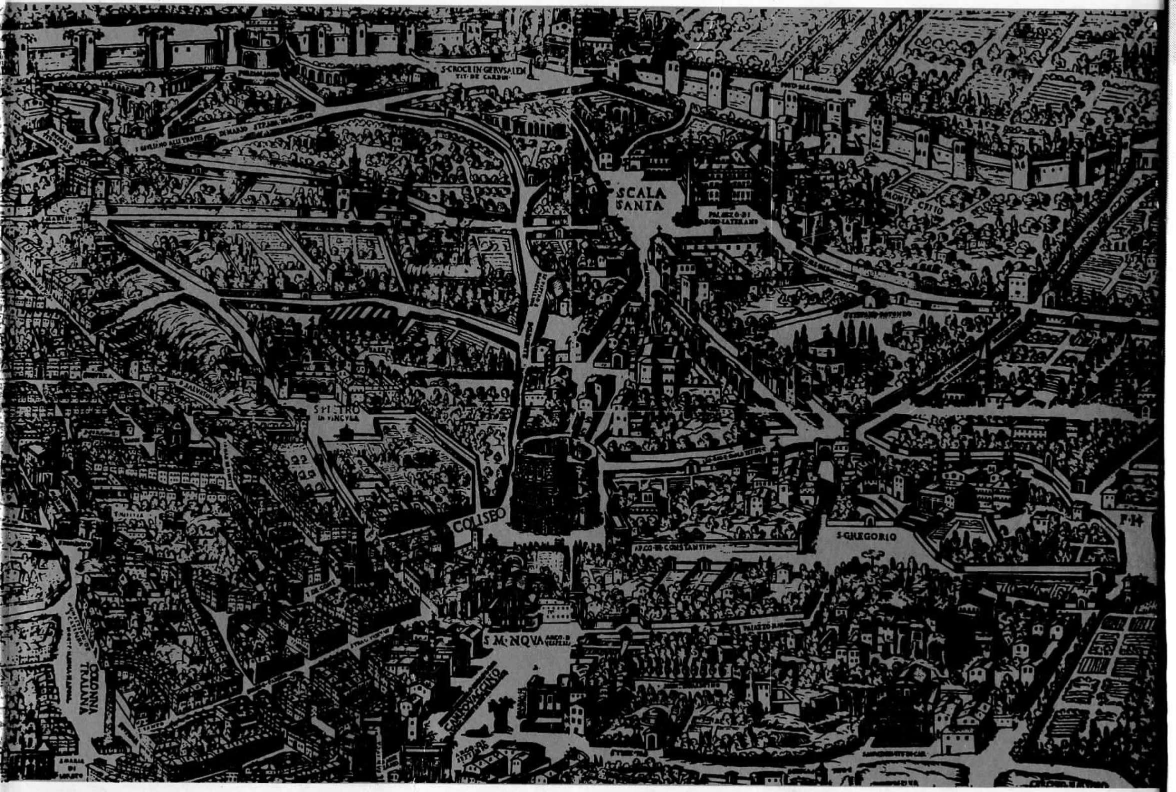

Alberto Sessa
(a cura di - édité par - editor)

La scienza dei sistemi per lo sviluppo del turismo

La science des systèmes pour le développement du tourisme
Systems science for tourism development

HEINO APEL

THE SYSTEM DYNAMICS MODEL OF GRINDELWALD

Opportunities and limits of a quantitative mo-'el in the analysis of socio-economic and ecological mountain systems.

Summary: 1. Introduction. 2. The limits of an economic-ecological system dynamics model. 3. The system dynamics model of Grindelwald. 4. Model analysis using the scenario technique. 5. Global system analysis: soft-coupling of different types of models.

1. Introduction.

It is well known that rural development and the expansion of tourism in the mountain areas may easily lead to a disequilibrium. On the other hand without tourism there is no chance for a self contained mountain agriculture.

The Swiss MAB-6 (Man and Biosphere) research project aims at the solution of the problem, i.e. what kind of precautions have to be taken that the mountain regions may serve even in the long run as living, economic, and recreational areas (1). These four test areas have been chosen: Grindelwald, Pays d'Enhaut, Aletsch, and Davos. Researchers from closely related Universities started to record ecological, socio-economic and cultural data. In describing and analysing observed processes in

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(1) Messerli B., Messerli P., 1978 «Wirtschaftliche Entwicklung und ökologische Belastbarkeit im Berggebiet» (MAB Schweiz). In: Geographica Helvetica 1978, N. 4.

a multidisciplinary systems approach we aim at a synthesis of the results on three levels:

1. The synthesis of the regional processes ('Project-Synthesis').
2. Problem oriented synthesis in the frame of a special scientific discipline (p.e. tourism, forestry, protection of the natural environment).
3. The overall synthesis for the mountain region ('Program-Synthesis').

In the beginning of the analysis the methodological way to gain these ends was not determined. Due to the lack of experience in systems analysis of multidisciplinary projects it was a part of the analysis to find 'a method' (or a boundle of methods) which could be applied by research teams and was suitable to solve the problems.

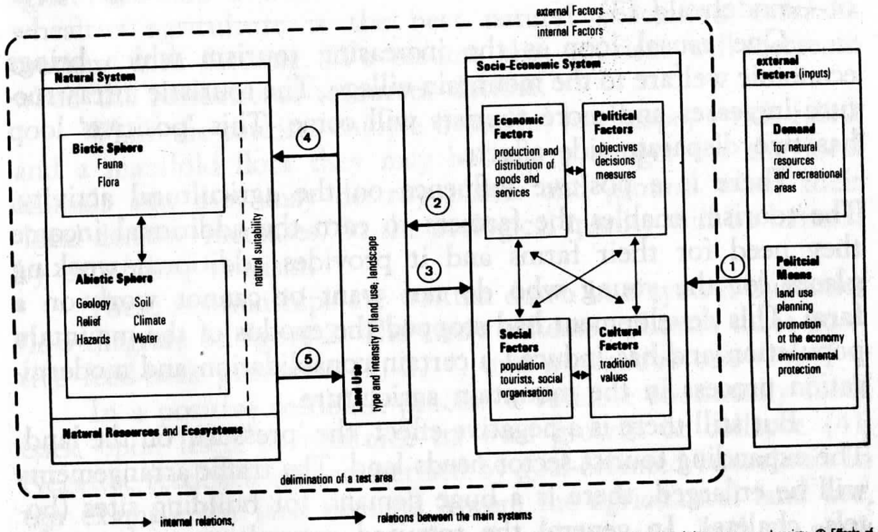
In other words there were two disparate methodological fractions: the *quantificateurs* and the *qualificateurs*. The first wanted to establish a global quantitative model (on a regional level) and the latter preferred a qualitatively oriented synthesis of the results describing it verbally. During the work the first approach was abandoned. The quantitative models mostly serve as a tool to clarify special questions for instance testing and finding hypothesis, that provide quantitative pictures to demonstrate simplified relationships, etc.

By the example of the test area Grindelwald I will at first demonstrate the difficulties in constructing a comprehensive system dynamic model which describes the socio-economic and the ecological processes of the region. Further I will give an outlook on the actual Grindelwald model. And finally I present the methodological frame in which the Grindelwald model will be used to derive synthetic conclusions.

2. The limits of an economic-ecological system dynamics model.

As stated above the MAB-6 approach aims at the description and analysis of a complete region which can be devided in a natural system, land use system and a socio-economic sistem. A very

Figure 1: Schematic representation of a regional socio-economic ecological system (by B. Messerli, P. Messerli in Geographica helvetica 1978, vol. 4).



① Influences of the external factors; ② Socio-economic development and connected change of land use; ③ Feedback of change in land use on population, economy and society; ④ Effects of change in land use on the natural system; ⑤ Feedback of the change in the natural system on the (human) condisions of living. (Figure published in GEOGRAPHICA HELVETICA, 1978, volume 4)

general overview is given in figure 1. Those schematic presentations (block diagramms) do visualise the scope of the task but nothing else. An arrow from one block to another hides more then it illuminates. In system dynamics modelling, which has been founded by J.W. Forrester, those arrows play a dominant role in constructing large 'spaghetti-diagrams'. They are easily designed and helpful to demonstrate plausible influences between elements of the considered system. But by going further i.e. to quantify the processes which are behind an arrow the difficulties arise.

Let us try to construct a typical Forresterian SD-Model of the complex drawn in figure 1 regarding Grindelwald. At first we have to clear up the main causal loops which seem to determine the processes of the region. The main force in a temporary tourist mountain town is the tourism itself. The coexistence between the modern tourist sector and the traditional agricultural sector, which can be still observed in most of the Swiss mountain regions, is to be characterized as the relation of a giant to a dwarf. In terms of the gross national product agriculture provides less than 2% of the regional GNP (2) and with regard to all indirect effects the tourism bears more than 90% of the GNP of Grindelwald (3).

One causal loop is the increasing tourism which brings economic welfare to the mountain village. The touristic infrastructure increases and more tourists will come. This 'positive' loop has two disparate side effects.

There is a positive influence on the agricultural activity. The tourism enables the farmers to earn the additional income they need for their farms and it provides additional working places for the young who do not want or cannot work on a farm. This development had stopped the exodus of the mountain population and has induced a certain consolidation and modernisation process in the mountain agriculture.

But still there is a negative effect, the 'pressure' on the land. The expanding tourist sector needs land. The traffic arrangements will be enlarged, there is a huge demand for building sites (hotels, chalets). In general the required grounds come from the valley's area which are the most fertile and hence most suitable for farming. So we find a direct competition between agricultural and tourist demand for land. It is obvious that tourism is the winner in this unequal competition.

But there is another important positive loop. We all know that the 'natural' landscape is in fact a 'cultural' landscape. Without the mountain farmer's work there will be no green meadows, and stable forrests, which can serve as a protection against avalanches. Fortunately, it makes no sense establishing highly intensive agricultural methods in a mountain region. We observe that the traditional ground management is still used except the

(2) Börlin M., 1982 « Das statische Input-Output-Modell Grindelwald. Abbidung der Wirtschaft 1980 und Simulation von Trendentwicklungen und von wirtscnaftspolitischen Massnahmen. Zürich 15. Juli MAB-Schlussbericht.

(3) Wiesmann U., 1984 « MAB-Grindelwald: Die Entwicklung des Fremdenverkehrs und dessen wirtschaftliche, gesellschaftliche un räumliche Bedeutung ». Doctorial theses, Bern.

degree of mechanization has changed. It turnes out that the mountain agriculture is still adapted to an ecological equilibrium. So we have the positive feedback between a well developed agriculture and a well maintained landscape. The fact that a whealthy agriculture is the best natural protection connects tourism with farming. We assume that tourism will decrease when the recreational resources decline.

While the tourists enjoy a beautiful landscape, a rich fauna and a manifold flora they may become a danger for the local animals and they may destroy plants and ground when their 'local density' increases. So the ecological quality will be harmed by expanding tourism.

These relationships are written down in a system dynamics flow diagram on figure 2. The arrow scheme indicates three positive feed-back processes (1, 2, 4) and a negative one (3).

In a positive feedback process a variable continually feeds back upon itself to reinforce its own growth or collapse (4). Negative feedback is characterized by goal-oriented behaviour. In our example the land demand lowers the agricultural land use, which will reduce the agricultural activity and lead to environmental deterioration this will finally lead to a decrease in tourism demand.

Without going into further details I want to demonstrate some serious problems that arise if those system pictures are to be quantified and analyzed:

2.1. *Model determination vs. indeterminated real system structures.*

It is the intention of system analysis to describe completely closed or open systems. This provokes an unsolvable problem if quantitative models are used to picture social systems.

No matter what the reasons are, in social science it does not seem possible to formulate neither simple nor complex laws

(4) Goodman M.R., 1974, « Study Notes in System Dynamics », Cambridge, Massachusetts.

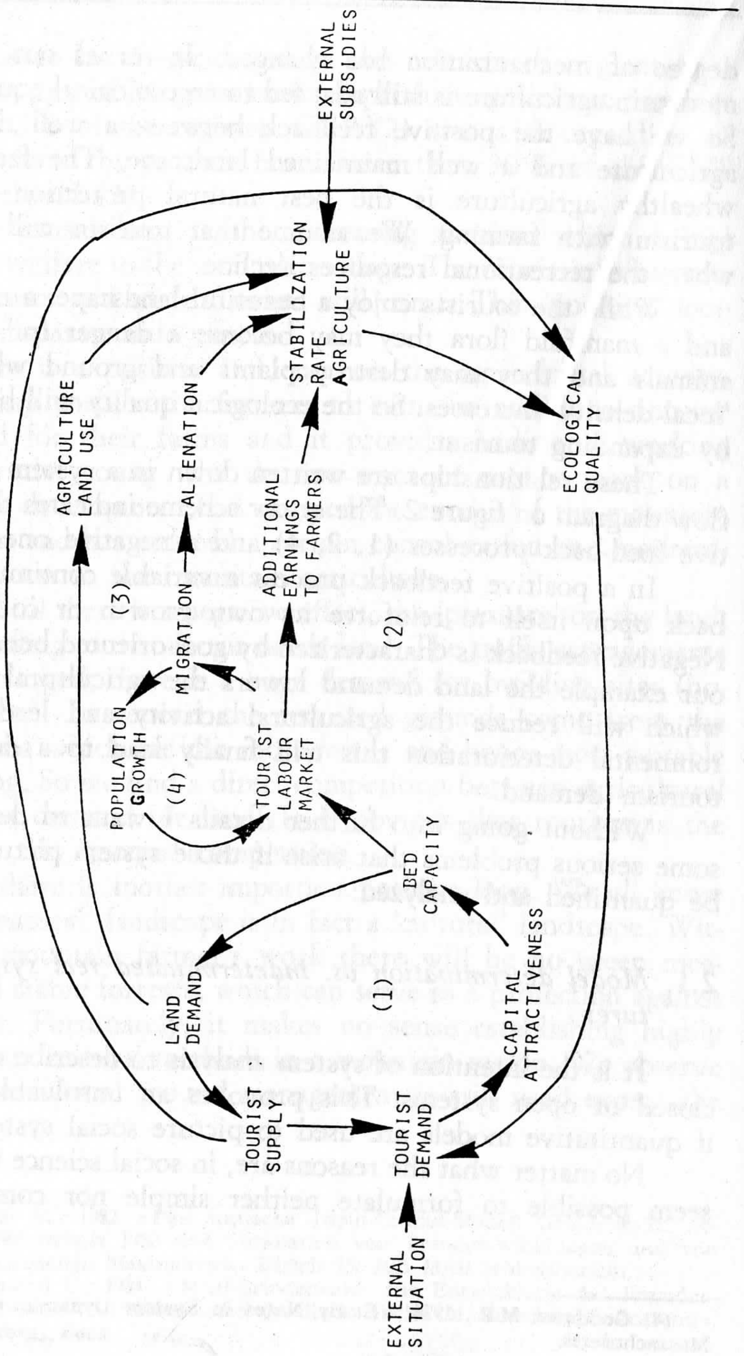


Figure 2: A system dynamics causal loop diagram of a regional socio-economic and ecological model.

which are able to predict accurately social behaviour. Social systems seem to have a non-determined structure.

But in any quantitative model we have to use strongly determined algorithmes. Of course there are some « tricks » in interactive simulation models to change the mathematical structure during the calculation procedure. But those changes have to be prepared, nothing is indetermined in a computer run.

In my opinion there is not much reason for a system analysist to think he/she would have the better quantitative tools than traditional researcher who describes single phenomena.

Looking at a scientific question, we have the opportunity to neglect all influences which we take to be irrelevant. Under the condition that those influences do not play a role we can formulate a law in quantitative terms which might be very helpful in understanding the phenomenon in question.

But looking at a complex social system it is very difficult to decide which influences we are allowed to neglect. Because of the indetermined structure of the systems behaviour they may or may not play a significant role. There is no determination about what questions may arise or what kind of solutions will be preferred. For the model builder it is impossible to design a super-structure which comprises all eventualities of future system behaviour.

When the model builder does not simplify reality enough, we will understand his model as less as reality itself. When he reduces reality too much, we will understand his model very well but the model will fail to predict any interesting system behaviour.

2.2. *Quantification problems.*

System dynamics modelling is a stepwise translation procedure from qualitative intuitive and expert knowledge to a mathematical quantitative representation. Often people forget that the degree of abstraction in qualitative descriptions is much higher than in quantified expressions. The relation between the declining ecological quality and the rising touristic supply in figure 2 might be a well based hypothesis in qualitative terms. But the statement:

ecol.quality = 0,5 / tour.supply

might be absolute nonsense if expressed in quantitative terms. Quantifying a problem means to become more concrete, i. e. that we must have additional knowledge which we often do not possess. Nearly every arrow in figure 2 expresses a serious theoretical and empirical problem. The most variables of the figure are inadequate for being used as quantitative expressions. We have to look for « indicator variables » which are representative, observable, and can be measured uniquely. In most cases these indicators do only express partly what in theory is meant and it is difficult to interpret their sample values correctly.

But in the context of a quantitative model the combination of « soft » qualitative indicator variables with « hard » quantitative variables leads to simplifications which can hardly bejustified. In those cases often the theoretical need for complete qualitative description leads to quantitative expressions which are highly tentative and without of empirical contents.

2.3. *Aggregation problems.*

The combined analysis of very distinct aspects in social systems may require different levels of aggregation. This is especially the case if social phenomena must be combined with ecological processes. In economics we may use a meaningful function to describe the sales of a sector of a whole country. But it would be a nonsense if one function describes the spread of a certain kind of vegetation over the whole country. In the latter case we have to introduce a partitioning of the country's surface. Then, howevers, it becomes very hard to formulate functions that allow to describe the sales of a sector which belongs to one partitioning.

The model builder has to look for compromises. So in practice we find two types of environmental models: socio-economically oriented with very insufficient links to the natural sistem, and pure ecological models with only very weak socio-economic references.

2.4. *Lack of theory.*

Since the early 70th system theory is en vogue. But looking at the countless famous and less famous literature we still find a lot of general advises, of methodological hints and descriptions of quantitative instruments but we do not find a new general theory which could be serve as a base for interdisciplinary analysis.

The best we may find are some multidisciplinary approaches; that means the addition of some formal aspects of different scientific disciplines in one quantitative model. As a consequence the quantitative design of a social system is often rather arbitrary piecemeal using « prefabricated » partial theoretical approaches. Therefore it is hard to overcome the discrepancy between the holistic philosophy and the reality of research which puts together simply single pieces.

After all these critical comments people may ask why should we use system-oriented models at all? I will make you three points:

1. Even though we cannot redeem the high claim of system theory it is necessary to look at the wide spread of interdependencies of most phemomena in our modern world. A quantitative model which aims at the complexity asks for unknown data and unknown thoeretical relations. In constructing this model we may better learn what we don't know and we will be compelled to reveal the basic assumptions. Thus quantitative models are helpful tools in clarifying of complex contents.

2. Complex systems are hard to overview where we use a verbal description. Developing a quantitative model which produces plots of the most important variables helps very much into understand the analytical consequences of our analysis. Models are « quantitative illustrators » of our assumptions.

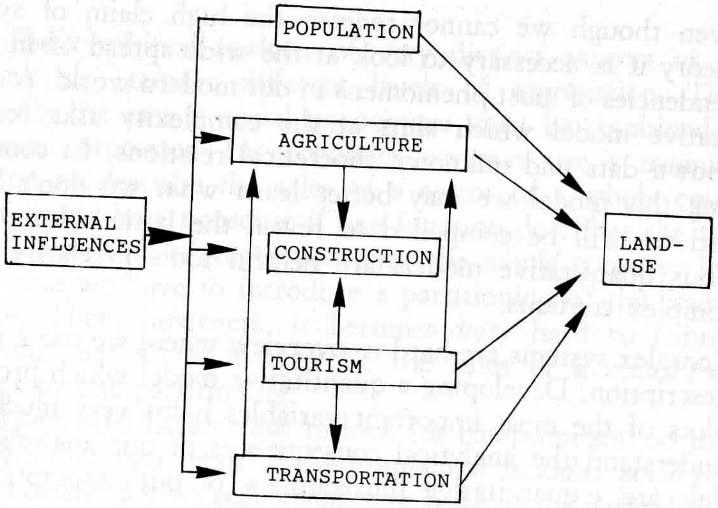
3. People like to have quantitative information. The model helps us to provide it. I would not trust computer work too much but in the sense of public relations it may help to support the results of our analysis.

3. The system dynamics model of Grindelwald.

The socio-economic process of Grindelwald is characterized as an extremely open system which is mainly determined by the tourism demand. From Grindelwald's point of view the tourist demand must be regarded as given because it is in competition with other tourist supplyers of the Swiss mountains. Futhermore there is no other sector independent of the tourist influence. There is a certain linear chain from tourist demand to the local tourist supply, to commerce, transportation, and construction.

Thus we have to understand this region as a system of « linear » adaption processes rather than a system of strong feedback processes. Therefore the Grindelwald model is closer to a linear regression model than to a typical system dynamics model.

The following figure 3 reveals the block structure of the model:



The population, transportation and land use modules have a very simple structure. They are implemented only by some technical equations; differentiated processes are not considered. The modules of agriculture, tourism, and construction follow a highly aggregated macroeconomic model approach on a regional level. In contrast to typically Forresterian SD-models there are no complex and aggregated variables, which cannot be directly observed or measured. In principle it is possible to estimate the behavioural equations by econometric methods (5). In system theoretical terms the overall level of the system is controlled by the tourist demand (with table functions) externally given, and the internal adaptation processes are guided by investment feedbacks.

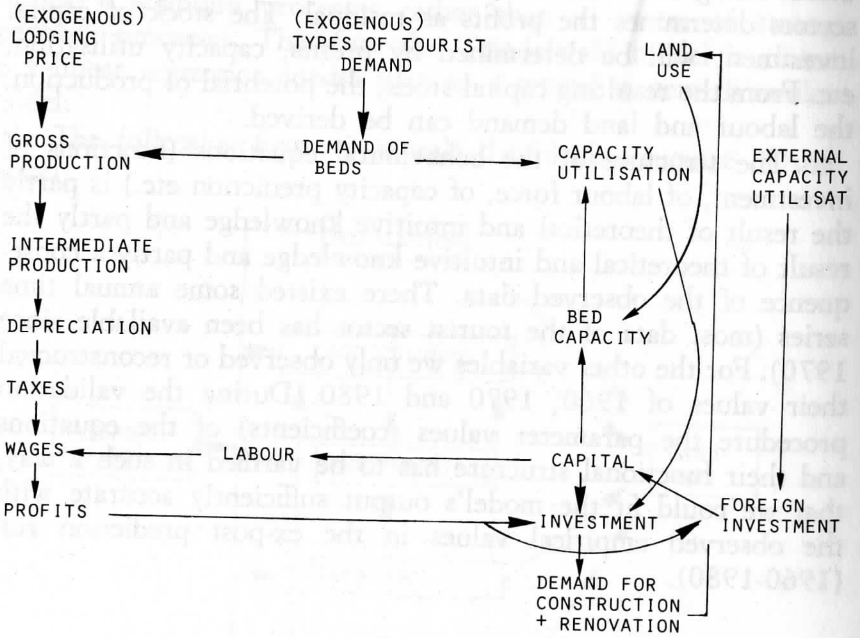
The economic structure is characterized by four elements. There is a technical production function which determines the gross production as a technical relation (i.e. lodgings times prices). Then the gross national product calculation of this regional sectors determines the profits as residual. The stock of capital investment will be determined by profits, capacity utilisation, etc. From the resulting capital stock, the potential of production, the labour and land demand can be derived.

The structure of the behavioural equations (functions of investment, of labour force, of capacity prediction etc.) is partly the result of theoretical and intuitive knowledge and partly the result of theoretical and intuitive knowledge and partly a consequence of the observed data. There existed some annual time series (most data of the tourist sector has been available since 1970). For the other variables we only observed or reconstructed their values of 1960, 1970 and 1980. During the validation procedure the parameter values (coefficients) of the equations and their functional structure has to be varified in such a way, that we could fit the model's output sufficiently accurate with the observed empirical values in the ex-post prediction run (1960-1980).

(5) Apel R., 1978, « Simulation sozio-ökonomischer Zusammenhange », Darmstad.

The agriculture module is divided in two sectors, the small (less than 10 ha) and the normal farms. In mountain areas big farms do not exist. The production depends only on technical restrictions i.e. capital that exists as machinery and buildings, and the surface that can be used for agriculture, because we do not have a competitive and functioning market in agriculture. Since the arable land is limited small and normal farms compete for the land. When the normal farms increase in size the number of small farms must decrease. When the land use for tourism increases both small and normal farms suffer a corresponding loss of land. In an economic sense the investment function is rather curious, because investment is guided by external income. It is dependent on the governmental subsidies and the additional income.

Figure 4: Flow diagram of the main variables of the hotel submodul.



The tourism module is devided into two parts: hotels (either owned by local or other Swiss people) and boarding-houses with

the same decision of owners. The distinction between local and other owners has been necessary because there has been an immense growth of non-local ownership in the past that lead to a displacement of local people through competition. We have to expect that the non-local owners decide rather on economic grounds than traditional rules that support local interests.

As an example the flow diagram in figure 4 shows the main relationships of the hotel submodule. In the framework of this paper I cannot discuss the model's structure in detail. Using the model for forecasting purposes (scenario technique) it turns out that the model's structure which has been estimated using the data sample of 1960 to 1980 (growth phase) si inadequate to produce a meaningful output if the future development stagnates or declines.

I had to change the investment equations and depreciation ratios fundamentally by adjusting the endogenous development to the lower growth ratios of the tourist demand. These necessities to correct the model is more than a model fit, it expresses the structural difficulties if tourist towns leave the growth path.

In the model the dynamics of the structural development of tourism in Grindelwald depends partly on exogenous phenomena and partly on the investment behaviour of local entrepreneurs. Tourist demand is partitioned into three types of tourists. According to their respective preferences these types choose between: lodging in hotels, in locally-owned, or in non-locally owned boarding-houses. These individual preferences of tourists and their consequences for the natural system had been analyzed for Grindelwald by U. Wiesmann (6).

The construction module is devided in the sector overground and underground building and the remaining part of the sector. The demand of construction is related to the investment activity of the other model sectors or given by table functions if sectors like government, commerce etc. are not in the model.

(6) comp. (3).

Comparable to the tourist modules the equations of the investment functions had to be changed if the economy entered in stagnation or crisis. During the growth phase a mainly profit-oriented behaviour of investment could be observed and estimated. In the other phases I had to postulate a simple adoption to the capacity utilisation and/or to the growth ratios.

4. Model analysis using the scenario technique.

For analyzing the system's (or more accurate the model's-) behaviour we use the scenario technique while changing the given tourist demand and related parameters and looking at the resulting adaption capabilities, especially the consequences for the land use and the labour market. The scenario technique should help to overcome the weakness of the classical forecasting procedures. Social systems do not have one determined future. The predictions of most of the past models have failed. The best we can do is to draw conclusions which hold under certain conditions.

Figure 5: Matrix-scheme of the postulated MAB-Swiss scenarios (7).

	ENDOGENOUS POLICIES			
EXOGENOUS SITUATION	no special policy	active policies promotion of tourism	promotion of tourism + agricult.	of natural protection system
growth	resignation			
stagnation	laissez faire			
crisis	breakdown			

(7) Apel H., Wiesmann U., Messerli P., May 1983 « Zur Szenariotechnik im schweizerischen MAB- Programm », Bern, unpublished paper.

In case of the scenario technique we postulate rather consistent images as a given condition and ask for consequences of those conditions.

In the MAB-Swiss project these postulated images (scenarios) are characterised by the national economic situation and the policy persued by the local authorities (compare figure 5). The time period for the scenario is 20 years (1980-2000).

The exogenous economic situation and the endogenous policy is generally formulated for the four test areas (7) and must be adapted to the specific situation of Grindelwald. This leads to the growth rates and the other parameter values of the exogenous variables of the model.

For the scarce manpower we cannot analyse the 12 possibilities of scenarios given by the matrix in figure 5. As a research strategy the first column was analysed at first. The question was what problems would arrive under the different economic situations when people do not have an active policy. The catalogue of these calculated problems gives us hints for the formulation of meaningful policies which may avoid serious instabilities in future system behaviour.

The surprising result was that Grindelwald is not a catastrophic system. There are relatively high buffer capacities which provide a good protection against « normal » perturbations.

The scenario of growth is simply a prolongation of the past pattern. The consumption of land by tourist demand increases, the concentration ratio of farms is expect to have a cultural given limit, the scarcity of labour force will decelerate the development. And it seems possible that extreme kinds of exploitation, which may hurt the natural system seriously, could be avoided. The scenario of stagnation produces serious problems in the labour market of the construction sector during the end of the century. This sector will need a high adaption capacity if unemployment should be prevented.

The scenario of crisis (from 1985 till 1990 and then slow growth) gives rise to more serious problems. After 1990 Grindelwald will have an unemployment of about 30% and probably most of the small farmers will not be able to cultivate their land because they miss their additional income from the tourist sector. The latter leads to abandoned fields and meadows which form a zone of potential ecologically instability which includes the danger of landslides and avalanches.

Of course, the mainly socio-economically oriented model cannot describe the whole system of Grindelwald completely. The combination of socio-economical phenomena and ecological processes requires a change of the aggregation level.

5. Global system analysis: soft-coupling of different types of models.

As stated above we did not trust a general and global mathematical systems model. Besides the SD-model land use models have been developed which are based on a data bank that is partitioned in small land units. In the data bank every land unit is characterized by a bundle of ecological, agricultural, and partly tourist indicator variables. With laws of successions or with matrices of transition the model can predict the change of the land use on a local scale if a change in land use is expected. These models allow a high aggregated input, and they result in a locally disaggregated ouptut, that may be a geographical map. In some cases we are able to calculate balances including all units. For example we may ask, what happens if a certain degree of agricultural intensification takes place. As input we need capital equipment (level of indoor and outdoor machine equipment) and intensity of labour. The output will be a map which enables us to calculate the most sensitive locations where the environment could irreversibly damaged. Another result is the yelds for each land unit can be calculated for each level of intensification. Thus we may start with one specific scenario. This gives us a frame of economic development in terms of aggregate values of variables in time calculated by the SD-model. The qualitative progress of the values of the models variables or even some special aggregate values have to be interpreted as inputs for the land-use models. Then we have to interpret the calculated local consequences; especially we have to look for inconsistencies. Next we can ask, how people may react to this outcome and go back to the initial scenario and change a policy. Furthermore it is possible to construct several concepts of land-use belonging to only one scenario. For example growth of tourism may take place locally concentrated or locally spread out. Both variants are characterized by the same numbers of lodgings but they do have very different consequences for land use and even for the labour market (8).

The MAB-Swiss project is just in the phase of constructing a systems synthesis by coupling together the different model types and levels of observations. There is no methodological straight-foreward way that leads to a guaranteed success. You may look at soft-coupling as art of soft modelling.

(8) comp. (3).