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An Introduction to the "I.S.P." System for Land Use Planning

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AN INTRODUCTION TO THE "I.S.P." SYSTEM FOR LAND USE PLANNING

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PREFACE

Since 1979, the Regional Development Group at IIASA has been engaged in a case study of economic and demographic development, land-use, and related problems in the region of southwestern Skåne in Sweden. The case study is the third in a series of attempts made by the Regional Development Group to apply systems analytic methods to regional planning problems in regions with different economic structures, resource endowments and organizational settings.

The research in the Swedish case study has been done in collaboration with the Intermunicipal Association of Southwest Skåne as a part of their ongoing work in physical and public transport planning for the metropolitan region of Malmö, and its neighboring municipalities. The research has been partly sponsored by the Swedish Council for Building Research.

In the case study an integrated systems analytic package of models is used which has been developed within the Regional Deveopment Group in cooperation with a group of Swedish researchers and planners. In that package, separate models have been developed for interregional economic and demographic problems, and for intraregional land-use problems.

As a part of the Swedish case study, the ISP (Interactive Spatial Planning) system was developed to assist in the design and study of land-use planning options. The ISP system represents a departure from many large-scale planning models, in that it is designed to be used by the planners themselves. Planning options and policies can be interactively defined in the system and the consequences quickly determined and studied through the use of computer graphic displays.

The interface to the model is through simple commands which enable a user to chart his own approach to setting up and analyzing each planning option. Considerable flexibility exists to include a range of planning policies through the use of special constraints on the forecasting model. Solutions can be quickly generated and compared across a range of performance indicators which enable the user to study the multiattribute consequences of each planning policy.

The model was jointly developed by the authors (Geoffrey G. Roy, of the University of Western Australia, and Folke Snickars, of the Regional Development Group at IIASA).* The current paper contains an overview of the main elements of the model system and its use.

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1. INTRODUCTION

Regional planning problems invariably occur within the context of diverse philosophical views as to the role of planning authorities to form, or control, the physical nature of both urban and rural regions. It is now no longer sufficient to base planning proposals on the "economic efficiency" of the regional system. Though still important, economics must take its place among a range of social and political objectives which will form our future social structure.

It must be recognized that regional systems are highly complex, generally defying accurate modelling. We are always confronted with the need to make simplifications in our attempts to reach an explicit description of the system. Any attempt at modelling must accept this difficulty at the outset. In presenting a description of the ISP system we are acutely aware of its limitations. We do suggest that the general structure of the ISP model offers advantages which make it useful in an environment of rapidly changing community attitudes towards planning policy.

At the outset, the ISP model was designed to attempt to fill the gap existing between large scale regional models and the needs of practising planners who must implement the results of such models. This gap is not trivial and the credibility/relevance of many modelling attempts may depend significantly on appropriate working relationships between theory and practice. The design of ISP has hence been aimed at bringing together a regional model and the planners in a way where communication and interchange between the two is not only simplified, but also relevant to the usual planning practices of the planner.

It should be explained at the outset that the ISP system will not, by itself, provide any answers to planning problems. The system will, however, assist planners to define, analyse and compare alternative planning strategies. The system is interactive and assumed that it is to be operated by planners in planning offices. It is envisaged that a user of the system will use it as a part of his ongoing planning operations. New information and changing planning policies can hence be tested in the system to reveal the consequences for the planning objectives.

The ISP system is controlled by user commands which enable a user to track his own path through the variety of options which enable planning policies to be input for evaluation. Considerable use is made of computer graphics to display the output from the ISP model. In this way a user can quickly and easily gain information without the need to examine large amounts of numeric data. The numeric data is always available where longer term or more detailed examinations are required.

The ISP system was developed for application in the Skåne region of southern Sweden. The examples quoted in this report are all taken from this case study. A detailed description of the ISP system can be found in Roy and Snickars (1981, 1982) and the detailed operation of the system in Roy (1981 a,b).

2. MODEL CONCEPTS

The ISP system is designed specifically for the problem of land use allocation (or zoning) in a regional context. The basic model of the region includes physical, economic, production and other necessary relationships between the various sectors and sub-regions composing the regional system. The common base for all these elements is the allocation of land to activities across the region and over a number of planning time periods.

The model assumes that the future states of the region are heavily influenced by the existing state. The existing state must, therefore, be well-defined both in terms of land usage and appropriate levels of production. Production for each sector can be defined in any appropriate units (e.g. monetary value, employment, quantity of production, numbers of people, areas of land etc.), but each must be convertible into land consumption. It is acceptable to have some sectors in the model even if they consume no land (or only minute amounts) if they provide necessary linkages between other sub-sectors. In formulating the future states of the region, the temporal variations in the production coefficients (i.e. the ratio between production and land consumption) must also be estimated from past trends or some knowledge of likely changes in production technology.

To approximate the real regional system each activity type must be classified into a set of sectors which can be sensibly managed by the model. At this level, the model should represent a reasonable approximation to the real situation. Further aggregations will often be necessary to bring the sectoral description in line with the land use classifications available to the planners. In the Skåne study, 26 sectors were chosen to represent the nature of the regional system and these were aggregated into seven sectors corresponding (approximately) to the broad land use classifications recognized by the local planners. (See Table 1).

The spatial characteristics of the region must also be approximated by the case of a set of sub-regions in which we can assume some uniformity of sector characteristics. In the Skåne study, 35 sub-regions were chosen. Often the choice of these

PRODUCTION SECTORS

1.	Crop production	- crop	Group 1
2.	Meat production	- meat	1
3.	Vegetable production	- vege	1
4.	Forestry	- fore	1
5.	Food industry	- food	2
6.	Chemical industry	- chem	2
7.	Equipment industry	- equi	2
8.	Other industry	- othe	2
9.	Utilities	- util	3
10.	Petroleum industry	- petr	3
11.	Wholesale trade	- whol	4
12.	Retail trade	- reta	4
13.	Private services	- priv	4
14.	Single family housing	- sing	5
15.	Multi-family housing	- mult	5
16.	Education	- educ	6
17.	Health care	- heal	6
18.	Public administration	- publ	6
19.	Roads	- road	0
20.	Railways	- rail	0
21.	Harbours	- harb	0
22.	Airports	- airp	0
23.	Person Transport	- pers	4
24.	Goods transport	- good	4
25.	Recreation	- recr	7
26.	Coast	- coas	7

PRODUCTION GROUPS

1.	Agriculture	- agrb
2.	Industry	- indb
3.	Energy	- eneb
4.	Service	- serb
5.	Housing	- houb
6.	Government	- govb
7.	Slack	- slab

TABLE 1: Production sectors for the Skane study

SUB-REGIONS

1.	Löddeköpinge	lodd	Group 1
2.	Kävlinge	- kavl	1
3.	Bjärred	- bjar	2
4.	Lomma	- lomm	2
5.	Lund	- lund	3
6.	Südra-Sandby	- sand	3
7.	Dalby	- dalb	3
8.	Genarp	- gena	3
9.	Veberöd	- vebe	3
10.	Hjärup	- hjar	4
11.	Staffanstorp	- staf	4
12.	Akarp	- akar	5
13.	Arlöv	- arlo	5
14.	Malmö	- malm	6
15.	Oxie	- oxie	6
16.	Bunkeflo	- bunk	6
17.	Bara	- bara	7
18.	Svedala	- sved	7
19.	Vellinge	- vell	8
20.	Höllviks-Näs	- holl	8
21.	Skanör	- skan	8
22.	Anderstov	- ande	9
23.	Smygehamn	- smyg	9
24.	Trelleborg	- trel	9
25.	Helsingborg	- hels	10
26.	Landskrona	- land	10
27.	Eslöv	- eslo	10
28.	Sjöbo	- sjob	10
29.	Ystad	- ysta	10
30.	Angeholm	- ange	10
31.	Klippan	- klip	10
32.	Hässleholm	- hass	10
33.	Hörby	- horb	10
34.	Kristianstad	- kris	10
35.	Simrishamn	- simr	10

REGION GROUPS

1.	Kävlinge Kommun	- kavk
2.	Lomma Kommun	- lomk
3.	Lund Kommun	- lunk
4.	Staffanstorp Kommun	- stok
5.	Burlöv	- burk
6.	Malmö Kommun	- malk
7.	Svedala Kommun	- svek
8.	Vellinge Kommun	- velk
9.	Trelleborg Kommun	- trek
10.	Rest of Skåne	- rout

TABLE 2: Subregion divisions for the Skane study

regions may not coincide with the local planning policies (e.g. corridor development, growth centres, etc.) and hence further aggregation is desirable. In the Skåne study the sub-regions were aggregated into municipalities (9 municipalities) plus one group containing several municipalities (see Table 2). In this way the spatial aggregation was designed to be appropriate for the SSK (Sydvästra Skånes Kommunalforbund) which is composed of 9 municipalities and is the planning authority for those regions.

The application of ISP requires, therefore, both spatial and sectoral aggregations as a means to simplify the complex regional system. Each application of ISP may well lead to quite different aggregation procedures and outcomes depending on the nature of each particular planning problem.

The two levels of description for the region are called the micro and macro states. The micro state contains the most detailed description both spatially and sectorally. The macro state is composed of the aggregated sectors in the aggregated sub-regions and is intended should be the main interface between the model and users. It is at this level we would expect the planner to impose his broad scale planning policies by allocating land to the various macro sectors.

One of the major components in the ISP model is the mechanism by which it estimates the likely future states of the region. We have chosen to use a forecasting technique which assumes that, in general, the regional system is rather stable and that only predictable changes are to be expected. This means that we have adopted a rather conservative approach to planning, but not perhaps an unrealistic one. The changes that are predicted to occur over time are brought about by two principal mechanisms. Firstly, the general development of the region (e.g. population, employment, production, etc.) over time is taken a priori. That is, for a particular model configuration we must have determined from other sources the predicted overall state of the region. Now secondly, it will be the imposed planning policies of the user of the system that will determine the spatial and temporal distribution of sector production levels to meet the a priori defined region-wide characteristics. The forecasting sub-model which aims at making as little as possible change to the region over sequential time periods, can be interpreted in mathematical terms. In the ISP model this forecasting procedure is currently based on the concept of maximising the "entropy" of the future state compared with the existing state of the region.

Given that the future states of the system are forecast, as outlined above, the user of the ISP model must define a set of performance indicators to measure the performance of the regional system for each set of planning policies. It is intended that these performance indicators (or objectives) should be designed to provide a multidimensional view of each solution proposal to assist the user in making direct comparisons between alternative planning schemes. These performance indicators can take a variety of forms and need not be constrained by any mathematical restrictions providing they can be computed from the data available in the ISP system or any other user supplied data. Table 3 shows, as examples, some of the objectives implemented in the Skåne study.

The operation of the ISP model can be divided into three major steps. Firstly, where the user develops and imposes specific planning policies. Secondly, where the forecasting procedure evaluates the most likely states of the region at each of the planning time period horizons. And thirdly, where the user

PERFORMANCE INDICATOR	SCALING
1. Rate of rural to urban land conversion	1000 - mean <1000 slower than average >1000 faster than average
2. Local recreation standards	sq.m/person x 10
3. Proportion of multi family housing	% x 10
4. Accessibility to work	range 400 - 600
5. Ratio of basic/service employment	1000 - mean <1000 less than average >1000 greater then average

TABLE 3: Performance indicators implemented for Skane study

examines the results (i.e. performance) of the scheme and makes comparisons with other alternatives. These three steps are integrated into an interactive computer system which facilitates a high degree of user involvement with the ISP model. The user has available a set of commands which enable him to impose policies and examine results in graphical or numerical form. It is anticipated that a potential user of the system would require some training and familiarization but it is not assumed that any "computer expertise" is necessary.

3. IMPLEMENTATION OF ISP

3.1 General

In this section we will discuss some of the issues involving the implementation of the ISP system to a given regional planning problem. It must be emphasized that each application can be quite different, hence affecting the detail and method of implementation. The first real issue that needs to be established is the basic nature of the problem in hand and the characteristics of the regional system. The availability of data will, of course, also have a substantial influence. In addition, the nature, powers and function of the planning authority for which the system may be implemented must also be considered. This is of some importance since we have suggested that the "macro" level definition of the regional system should be related closely to the normal operation and powers of the planning authority.

3.2. Definition of Micro State

The micro state represents the finest description of the regional system and comprises a number of sectors allocated into a number of sub-regions. At this level we are generally constrained by two major factors, the availability of data and the capacity of the computer on which the system is to be operated. On the other hand, the evaluation of performance indicators may require a considerable level of detail in the regional model if realistic results are to be expected. Hence we have to balance up these conflicting aspects in the process of designing a suitable micro state definition. Tables 1 and 2 show the micro state definition for the Skåne Study by way of example.

Once the micro state is defined we must assume that each sector in each sub-region represents a uniform characteristic. By this we mean that it has a uniform consumption of land and that it can be considered uniform in its relationships with other sectors, both within and between sub-regions. We must accept that the micro state is the finest level of detail available for any computations within the model. We do assume, however, that the planners interest may go beyond this and he may impose (externally to the ISP model) certain additional information in selected areas of interest. Such a process will, in general, be not only desirable, but essential in the practical implementations of the ISP model.

3.3 Definition of Macro State

The macro state should relate as closely as possible to the normal planning methods and powers of the planning authority. It is expected that some trial and error may be involved before a satisfactory macro state evolves. As explained earlier, the macro state involves both sectoral and spatial aggregations. The ISP system is designed to facilitate an easy re-definition of the macro state during the implementation process. Also, it may be appropriate for the user to evaluate fundamentally different planning strategies (e.g. corridor versus growth centres) which would involve a re-definition of the macro state. This is easily achieved in the ISP model. Each sector and sub-region at the micro level is given a group index number (see Tables 1 and 2) which associates it with the particular macro group. These index numbers are easily altered to suit user requirements. Depending on the requirements of the user, certain micro sectors and regions may not appear at the macro level. This implies that although the user may not be particularly interested in them, they still form an integral part of the total regional system.

In the case of the Skåne study, the macro regions correspond to the nine municipalities comprising the planning authority for which the ISP model was implemented. Here we have a "political" justification. In other situations a different basis would be used to select a suitable definition of the spatial character of the regions at the macro level.

Since the ISP model is designed for land use allocation, the macro sectors should correspond to the land use classifications which are normally used by the planning authority. Even though the micro sectors are defined in "production" terms and convertible into land, at the macro level we are mainly interested in land consumption. Obviously, however, we do need to still record the aggregated production values so that we can be sure to allocate sufficient land to accommodate the changing demands of various sectors across the region as a whole.

3.4 Definition of Performance Indicators

The performance indicators chosen to be implemented will need to be defined in close collaboration with the users of the system. In addition it may be appropriate to include performance indicators appropriate to other interested parties who are normally outside the planning authority (e.g. politicians, conservationists, developers etc.). The performance indicators have to be specifically programmed into the ISP model for each particular implementation. Two user written sub-routines must be included to provide data and to compute the necessary values for the performance indicators at each step in the forecasting model. The performance indicators are evaluated at three levels of spatial aggregation. Hence, for any indicator, the ISP model computes its value at the micro sub-region level, the macro region level and then at some global level across the whole (or part) of the total region. Each indicator is evaluated for each planning time horizon and currently no aggregation across time is done. At the global level, therefore, the user will be provided with each performance indicator evaluated for each time period. If desired, the user can also examine each indicator across macro regions or across micro regions.

It should be emphasized that each performance indicator is computed independently and hence there is no requirement that any common basis needs to be adopted. Each indicator can be measured in the most appropriate units and suitably scaled without reference to the others. For example, see Table 3 for the Skåne study performance indicators.

3.5 Computer Aspects

The implementation of the ISP model does require the existence of certain computational capabilities. The major requirement is for a graphics display terminal. Currently the system is designed for Tektronix (or Tektronix compatible) type displays. In particular, it does require a display with a reasonable degree of resolution (at least 1000 points across the screen) and a larger size screen being of considerable value. A high speed connection to the computer is also essential (at least 2400 baud), otherwise the graphic outputs will be painfully slow. A hard copy unit is also desirable to make copies of graphical displays.

The total ISP system does also require a substantial computer capability. It will run on most main frame computers and on certain mini-computers, depending on available memory and operating system. Computational times will generally be slower, but perhaps costs less. Computational times will only be significant in the forecasting sub-models which is executed once for every new trial solution. On the DEC 10 at the University of Western Australia, about 30 secs CPU time is involved for the Skåne study, while on a Nord 100 (a mini computer) in the city of Malmö (Sweden) the same problem takes about 8 minutes. Considering that most of a user's time will be involved in setting up and examining results, these times are considered satisfactory.

As each trial solution is generated it is stored permantly in the computer and the user is free to access any such solution for future reference. Initially we always assume that at least one solution already exists. This base solution would normally represent, for example, the current planning outlook or a non-intervention scenario. As more solutions are generated considerable disk storage could be required.

Normally, any solution generated can be accessed and reported on in an interactive fashion with various forms of graphical displays. For longer term reporting and recording, rather detailed numeric reports can also be generated via a line printer.

4. OPERATION OF ISP SYSTEM

4.1 General

In this section we will outline an example operation of the ISP system given that the data files etc. have been set up and are operational. We will use the Skåne case study as a means of demonstrating the capabilities of the system. Operationally, ISP is divided into 5 phases, each having a specific set of functions. The user is free (in general) to move amongst these phases to achieve the desired approach to the particular planning problem. In the description below we will take each phase in sequence, which is the usual, but not necessarily the only approach. Also, it is usual to commence interaction in Phase 4 (examination of results) where the user can report from previously generated solutions before going on to develop new alternatives.

4.2 Phase 1: Adjusting Macro Allocation of Land

In Phase 1 the user is required to impose some broad scale planning policies on the allocation of land to macro sectors across macro regions. This allocation of land must satisfy the a priori determined general development demands on land use. That is, if we must accommodate a growing population in housing and employment, then land must be allocated, or re-allocated, over time to meet those demands. The choice of which land and in which regions, is left to the user of the system. It must be remembered that at the macro level we are dealing with aggregations of sectors and regions and as such we believe that this task is by no means impossible for the planners. These broad scale policies are (usually) an essential element in the information the planner can impose to control the

Allocation phase
id

Time =1980

	agrb	indb	eneb	serb	houb	govb	slob
	326.*	324.*	18.*	1073.*	7082.*	2066.*	2.*
kovk ----*	11931.*	167.*	251.*	16.*	744.*	44.*	906.*
(-1838.)	11454.	169.	256.	17.	804.	41.	907.
lomk ----*	4105.*	22.*	6.*	12.*	439.*	32.*	469.*
(-504.)	3962.	18.	6.	13.	485.	38.	469.
lunk ----*	30437.*	229.*	44.*	97.*	1875.*	729.*	938.*
(-10410.)	29893.	223.	45.	98.	1927.	840.	938.
stok ----*	9395.*	81.*	3.*	21.*	469.*	45.*	156.*
(-1212.)	8942.	84.	3.	21.	489.	64.	156.
burk ----*	1022.*	154.*	19.*	48.*	213.*	26.*	75.*
(-348.)	909.	163.	19.	52.	212.	31.	75.
molk ----*	8344.*	1296.*	119.*	837.*	2226.*	552.*	1119.*
(-3190.)	7118.	1183.	121.	845.	2138.	625.	1120.
svek ----*	18472.*	32.*	6.*	1335.*	521.*	24.*	106.*
(-5283.)	16667.	33.	7.	1436.	629.	31.	106.
velk ----*	9553.*	22.*	13.*	16.*	918.*	57.*	2038.*
(-1623.)	9574.	22.	13.	15.	988.	67.	2039.
trek ----*	29816.*	271.*	25.*	97.*	965.*	70.*	1482.*
(-2990.)	28523.	254.	26.	112.	959.	79.	1481.
rout ----*	756731.*	3583.*	275.*	1596.*	23362.*	756.*	15758.*
(-161894.)	762857.	3561.	279.	1625.	24115.	950.	15758.

im,houb,molk,2200

FIGURE 1: Table of macro land allocations

future development of the region. Fig. 1 shows an example allocation of land at the macro level. This table is the basic mechanism to allow the users to make changes to the allocations. We will now describe this Table in some detail.

A Table (as in Fig. 1) showing the macro allocation of land exists for each planning period (1980, 1985, 1990, 1995 and 2000 in the Skåne study). The Table contains the allocation of land (hectares) for each macro sector (across the Table) in each macro region (down the Table). The rows and columns are labelled with the names of the sectors and regions. Within the Table the numbers between the "# .... #" are the values for the previous time period (1975, i.e. the base year in this example in Fig. 1). The figure immediately under these is the estimate for the current time period which can be altered by the user. In making adjustments, the user cannot totally ignore the allocation at the previous time state, hence those figures are always included for comparison.

Any figure in the Table (for the current time period) can be altered by the user using a command like the one shown at the bottom of Fig. 1. That is,"m,houb,malk,2200" will change the amount of land allocated to housing in Malmo Kommun to 2200 ha. The previous value being 2138 ha for 1980 and the 1975 figure was 2226 ha.

To assist the user in this allocation of land two more sets of data are included in the Table. Down the left hand side of the Table (immediately under each region name) the net amount of uncommitted land is given. This figure indicates for each macro region how much land is available for allocation. Obviously the user is not permitted to allocate more land than is available. Also along the top of the Table (immediately under each sector name) there is an estimate of by how much the production in each sector would exceed the region wide forecasts if all of the land allocated was in fact used by the sectors. The units are in "production" terms appropriate to the macro sectors. In this case, for example, agriculture is measured in employment, housing in numbers of people and slack land in land area. This information is necessary to ensure the user allocates sufficient land to allow the minimum levels of production to occur across the region as a whole.

In general the amounts of unused land should always be 0 or less while the amounts of "over production" should be zero or more. There are exceptions to this that will be explained later. Each time the user alters an allocation of land he should check these figures with a "verify" (v) command which evaluates the new values and prints suitable error messages if the above conditions are violated.

The user can step on to the next time period with a "next" (n) command or return to the previous period with a "back" (b) command to examine, and hence modify, any element in the macro allocation of land. Also, to enable the user to obtain a clearer picture of the temporal characteristics of his allocations, various graphical outputs are possible. A "g,agrb" command will produce a graph as in Figure 2, showing the allocation of agricultural land with time for each macro region. Also a "g,lunk" command will plot a graph showing for the region of the Lund the allocations of each type of land use over time (except agriculture in this case) as seen in Figure 3. These graphs enable the user to assess the temporal characteristics of his allocations. It is also possible to compare allocations from other trials and display them concurrently with

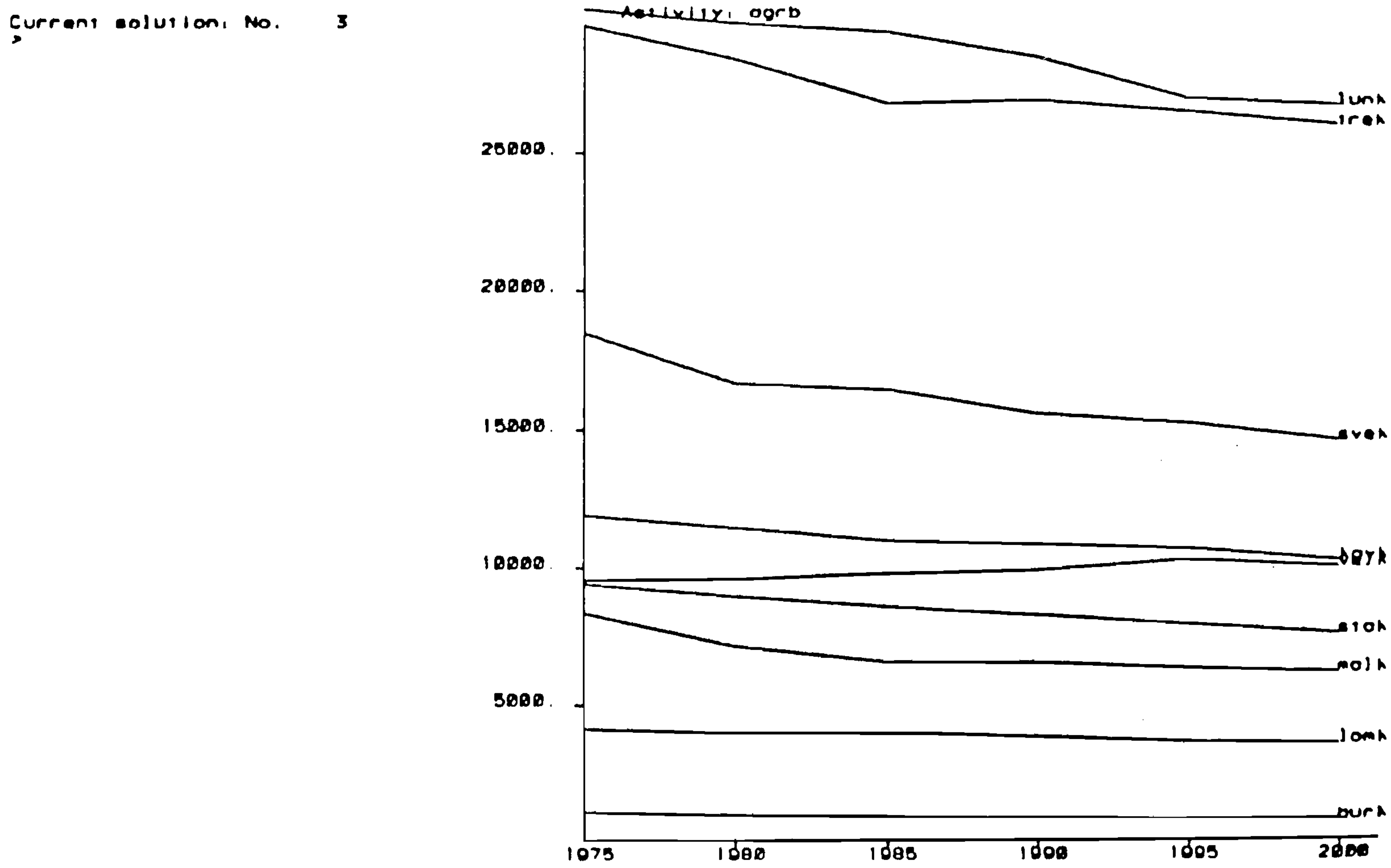

FIGURE 2: Plot of agricultural land in macro regions

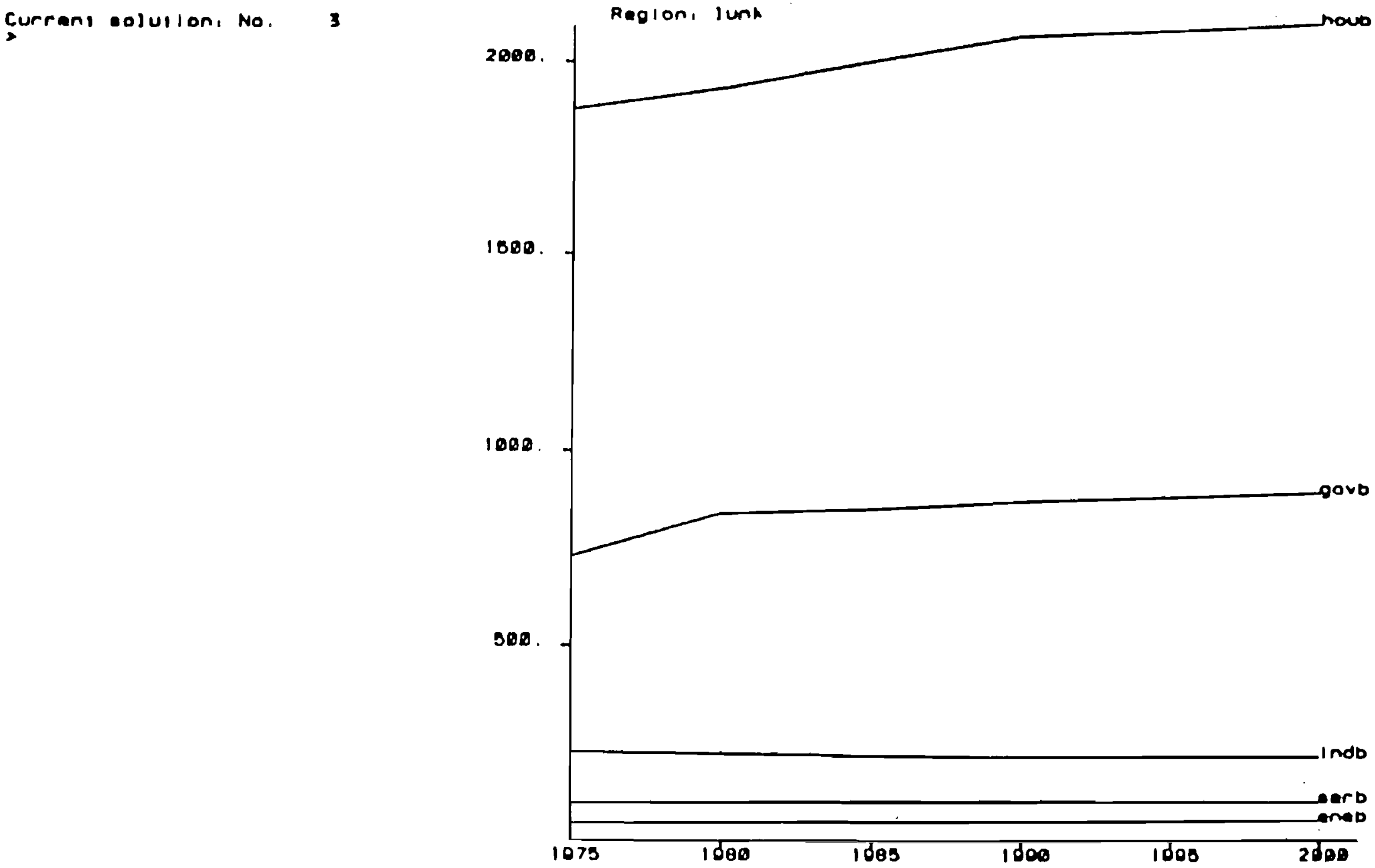

FIGURE 3: Plot of macro land allocations in Lund Kommun

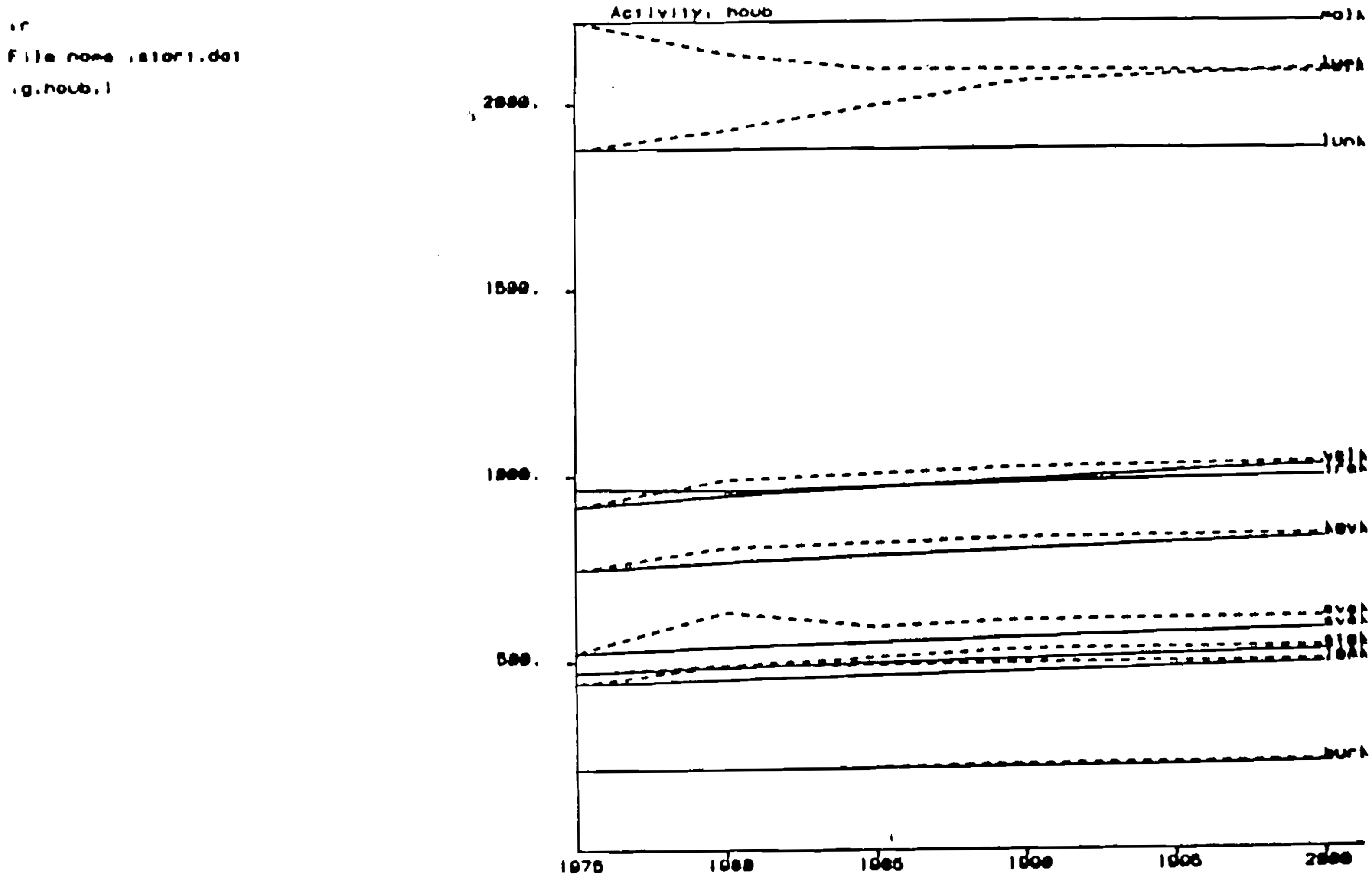

FIGURE 4: Plot showing comparison of two macro land allocations

the current trial as shown in Figure 4. In this case, the graphs shown in dotted lines are for some previously generated allocation.

To gain a visual impression of the spatial characteristics of the allocations a map of the region can also be plotted (see Figure 5). In this case we plot an outline of the macro regions and show by means of a "pie" chart the proportion of land allocated to the various macro sectors (again excluding agriculture in this case). Similar plots can be obtained for each planning time period.

The allocations of land made by the user are (by default) assumed to be upper bounds. That is, we assume that, in general, the user is really only interested in allocating just sufficient land to accommodate the regional development. In some situations he may over allocate land on the assumption that the model will ultimately only use a sufficient amount and an adjustment can be made at a later stage. It is possible, however, for the user to change this default condition in Phase 2 below. It is also possible for the user to make no allocations in selected sectors and/or regions if he so wishes.

Once the user has completed the required changes to the macro allocation of land he may then proceed to Phase 2.

4.3 Phase 2: Special Constraints

This special constraint phase provides the user with opportunities to impose a range of rather particular planning policies on the region. These policies are interpreted by means of constraints which will be imposed on the forecasting submodel. There are a range of special constraint types available to the user.

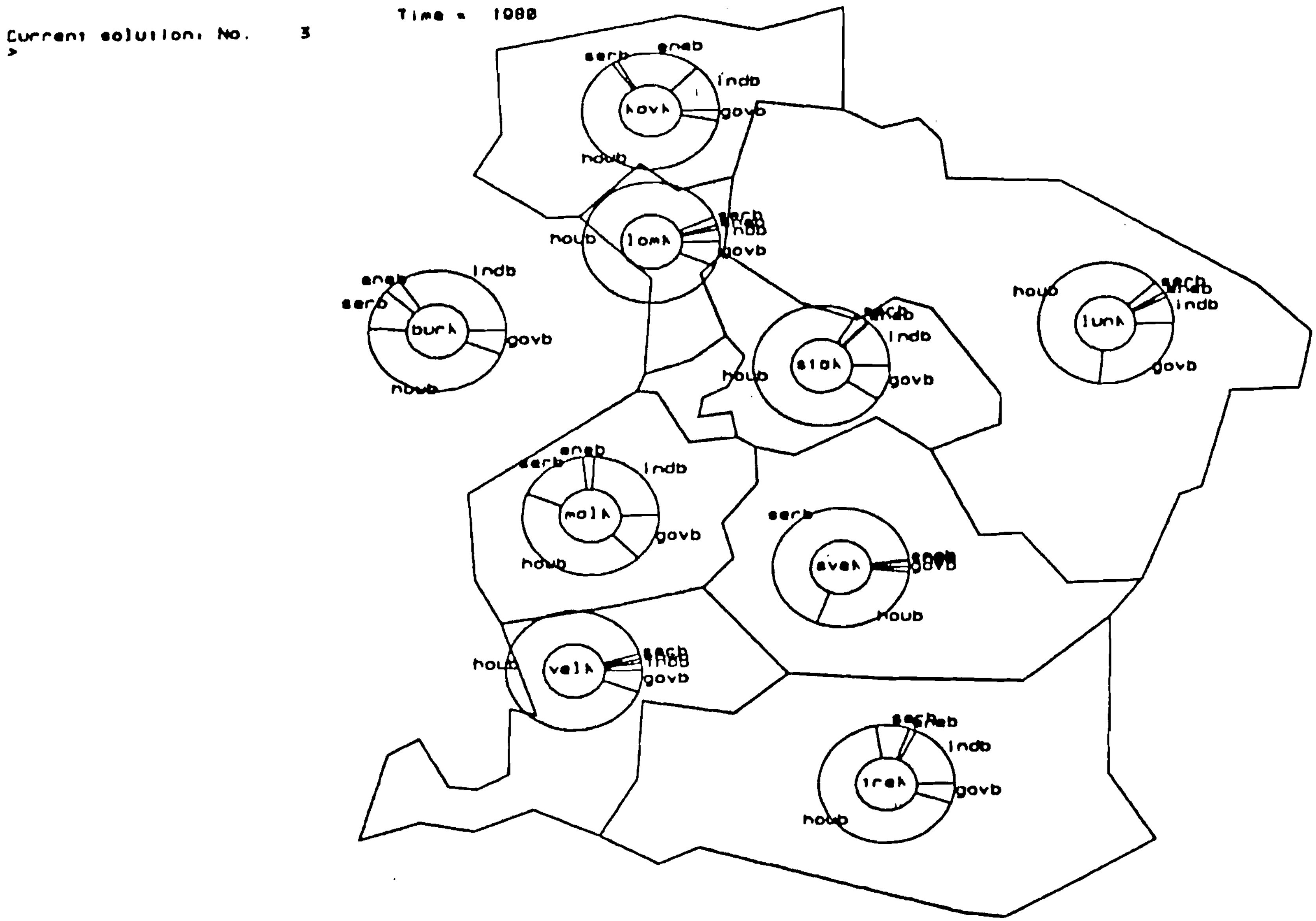

FIGURE 5: Plot showing spatial distribution of macro land allocations

(a) Single Variable Constraints

This is the simplest form and enables the user to impose simple constraints (upper or lower bounds and equalities) on any selected micro varibale at any (or several) time periods. Since each micro variable is defined (in the program) in units of production then it is at this level that the user operates (e.g. employment, number of people, quantity of production). An example of how these constraints are inserted is given in Figure 6. Here the "adds" command instructs the program to expect a single variable constraint. The user then inputs the actual constraint in the form shown in Figure 6a, using the appropriate sector and region names, together with the time period. Relational indicators "<" implying "≤", ">" implying "≥", "=" for equality and "*" for "don't care" can be used as desired. Figure 6b shows the capability to impose sets of constraints. By using general names "vall" to include all sectors, "rall" to include all regions and "Ø" to include all time periods, various sets of constraints can be included by one simple command. Figure 6c shows the result of the operations in Figures 6a and 6b which can be obtained by listing the currently active single variable constraints. Any single or sub-set of constraints can be modified as shown in Figure 6d. The modification is done to the right hand side and to the relational indicator for the constraint(s) with the matching left hand side.

(b) Ratio Type Constraints

In many situations the user may wish to provide some relationship between two different variables. For example, it may be considered appropriate to have some tie between the numbers of people living in different types of housing. Hence, in Figure 7 we have said that the ratio between single family housing (in

```
 adds
*crop,lodd,1990,<240
>
```

FIGURE 6a: Commands to insert single variable constraint

```
 adds
*vege,rall,1985,>100
>adds
*sing,lund,0,>35000
>
```

FIGURE 6b: Commands to insert sets of single variable constraints.

```
list,s

List of extra constraints-
     1: crop lodd 1990 <     240.00
     2: vege lodd 1985 >     100.00
     3: vege kavl 1985 >     100.00
     4: vege bjar 1985 >     100.00
     5: vege lomm 1985 >     100.00
     6: vege lund 1985 >     100.00
     7: vege sand 1985 >     100.00
     8: vege dalb 1985 >     100.00
     9: vege gena 1985 >     100.00
    10: vege vebe 1985 >     100.00
    11: vege hjar 1985 >     100.00
    12: vege staf 1985 >     100.00
    13: vege akar 1985 >     100.00
    14: vege arlo 1985 >     100.00
    15: vege malm 1985 >     100.00
    16: vege oxie 1985 >     100.00
    17: vege bunk 1985 >     100.00
    18: vege bara 1985 >     100.00
    19: vege sved 1985 >     100.00
    20: vege vell 1985 >     100.00
    21: vege holl 1985 >     100.00
    22: vege skan 1985 >     100.00
    23: vege ande 1985 >     100.00
    24: vege smyg 1985 >     100.00
    25: vege trel 1985 >     100.00
    26: vege hels 1985 >     100.00
    27: vege land 1985 >     100.00
    28: vege eslo 1985 >     100.00
    29: vege sjob 1985 >     100.00
    30: vege ysta 1985 >     100.00
    31: vege ange 1985 >     100.00
    32: vege klip 1985 >     100.00
    33: vege hass 1985 >     100.00
    34: vege horb 1985 >     100.00
    35: vege kris 1985 >     100.00
    36: vege simr 1985 >     100.00
    37: sing lund 1980 >   35000.00
    38: sing lund 1985 >   35000.00
    39: sing lund 1990 >   35000.00
    40: sing lund 1995 >   35000.00
    41: sing lund 2000 >   35000.00
>
```

FIGURE 6c: List of constraints inserted by commands in Figures a & b

```
mods

*crop,lodd,1990,=300

>list,s

List of extra constraints-
     1: crop lodd 1990 =     300.00
     2: vege lodd 1985 >     100.00
     3: vege kavl 1985 >     100.00
     4: vege bjar 1985 >     100.00
     5: vege lomm 1985 >     100.00
     6: vege lund 1985 >     100.00
     7: vege sand 1985 >     100.00
     8: vege dalb 1985 >     100.00
     9: vege sena 1985 >     100.00
    10: vege vebe 1985 >     100.00
    11:            985 >     100.00
                             100.00
```

FIGURE 6d: Command to modify single variable constraints

```
 addr
*sing,lund,1980,/
*mult,lund,1980,<2.5
>list,r
List of extra constraints-
    1:sing lund 1980/mult lund 1980<        2.50
>
```

FIGURE 7: Command to insert ratio type constraint

terms of people) and multifamily housing in the region of Lund in 1980 should be less than 2.5. The ratio constraint is added with the "addr" command. For this type of constraint, simple ratios between any two variables (i.e. any sector in any sub-region) in the same time period can be defined. Again this ratio can be an upper or lower bound or an equality. Ratio type constraints can also be modified as in the case of the single variable constraints.

(c) Bound Type Constraints

It is often useful to provide some dynamic constraints on certain variables over time. These are useful to affect the rate at which those variables change with time. The user can define such constraints for any selected variable. Figure 8 shows an example where the crop production (employment terms) in the region of Dalby is constrained to be greater than, or equal to, 0.9 of the level at the previous time and less than or equal to 1.1 times the same value over all time periods. Equality bounds are also allowed.

(d) Macro Land Constraints

As discussed earlier, we assume (by default) that the user defined macro allocations of land are taken as upper bounds. The user is free to change any of these to lower bounds. In Figure 9 equalities or "don't care" constraints are placed on agricultural land in the Kävlinge Kommun for all time periods and equalities on the slack land in the Lund Kommun, also for all time periods. In this case, the user can only change the relational indicator, the right hand side value being taken as fixed from the previously defined allocations in Phase 1 (see Figure 9).

```
addb
*crop,dalb,0,>.9
>addb
*crop,dalb,0,<1.1
```

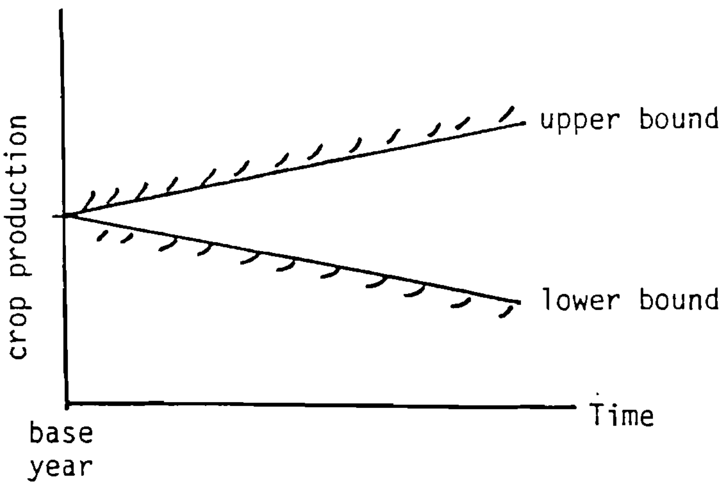

FIGURE 8: Command to insert bound type constraints

```
modm

*asrb,kavk,0,*

>modm

*slab,lunk,0,=

>list,m

asrb kavk 1980 *    11454.
asrb kavk 1985 *    10962.
asrb kavk 1990 *    10816.
asrb kavk 1995 *    10652.
asrb kavk 2000 *    10227.
slab lunk 1980 =      938.
slab lunk 1985 =      938.
slab lunk 1990 =      938.
slab lunk 1995 =      938.
slab lunk 2000 =      938.
>
```

FIGURE 9: Commands to modify macro land constraints

Once developed a set of special constraints can be saved for future recall, hence a user may develop several sets of constraints to represent distinct planning scenarios.

4.4 Phase 3: Solution of Forecasting Problem

Once the user has developed a set of special constraints (if required) then Phase 3 contains a set of procedures which set up and solve the forecasting problem. Using the base year as a starting point (1975 for the Skåne study) and selecting those special constraints active for the first time period (e.g. 1980) the forecasting problem is solved to give estimates of the new micro state. That is, the value of each sector in each sub-region. In addition, the values of the performance indicators are computed (at three levels: micro, macro and global). This procedure is automatically repeated for each subsequent planning period.

The user needs only to be concerned with this process if difficulty was experienced in finding solutions. Problems will arise if the user has imposed any mutually contradicting constraints resulting in an infeasible solution. In such cases the difficulty will be reported and the user will have to go back to Phases 1 and/or 2 to correct the problem. If the solution was successful, the program steps automatically on to Phase 4.

4.5 Phase 4: Reporting Phase

Phase 4 provides a variety of options for the user to examine and compare solutions. By default, the program reports from the most recently generated solution, but any solution can be selected by the user. We will demonstrate the options available in several classes:

```
show

Sol. No.       3           1975   1980   1985   1990   1995   2000
 rural-urb land conv      1000.   984.   975.   960.   947.   943.
 local recr. sids          901.   899.   895.   886.   876.   865.
 prop. mul-fam housi       603.   602.   600.   596.   590.   585.
 access. to work           486.   495.   504.   512.   513.   516.
 basic/service emplo       776.   777.   782.   784.   788.   793.
 Kovlinge agric wate        48.    47.    45.    45.    44.    43.
 Vombsjon ind water        143.   161.   181.   210.   247.   291.
 Vombsjon dom water       1831.  1821.  1820.  1828.  1827.  1830.
 Ronne agric water          26.    24.    22.    21.    19.    18.
 Ringsjon ind water          9.    10.    12.    15.    18.    21.
 Ringsjon dom water      18039. 18387. 18640. 18924. 19350. 19779.
Current solution: No.     3
>select,1

Current solution: No.     1
>show

Sol. No.       1           1975   1980   1985   1990   1995   2000
 rural-urb land conv      1000.   984.   975.   960.   947.   943.
 local recr. sids          901.   899.   895.   888.   883.   876.
 prop. mul-fam housi       603.   602.   600.   597.   594.   593.
 access. to work           486.   495.   504.   512.   513.   514.
 basic/service emplo       776.   777.   782.   784.   788.   793.
 Kovlinge agric wate        48.    47.    45.    45.    44.    43.
 Vombsjon ind water        143.   161.   181.   210.   247.   291.
 Vombsjon dom water       1831.  1822.  1820.  1828.  1834.  1843.
 Ronne agric water          26.    24.    22.    21.    19.    18.
 Ringsjon ind water          9.    10.    12.    15.    18.    21.
 Ringsjon dom water      18039. 18371. 18624. 18861. 19061. 19271.
Current solution: No.     1
>
```

FIGURE 10: Table of performance indicators at global level

Current solution, No. 4

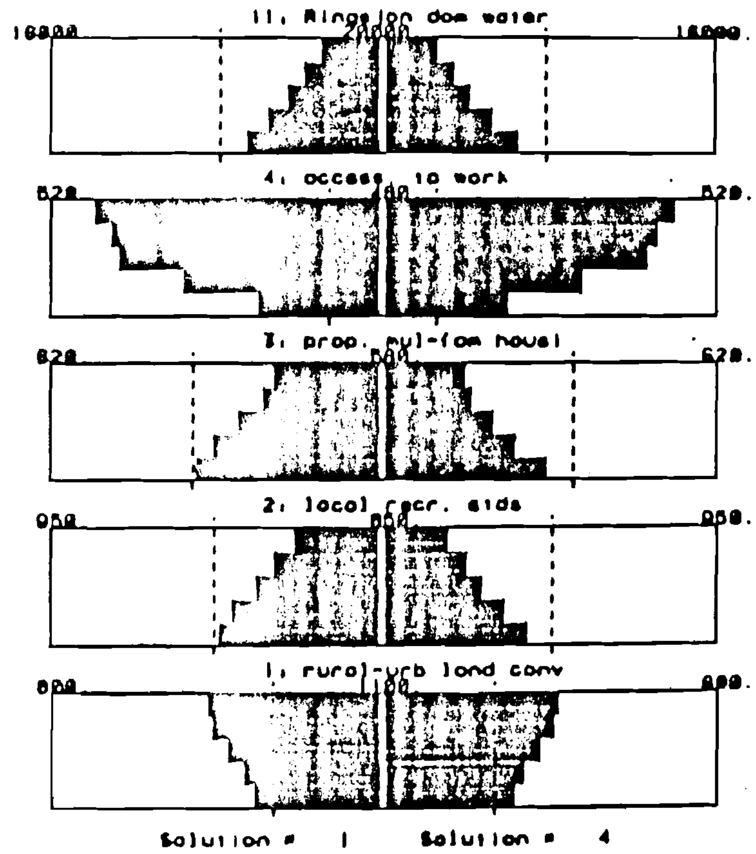

FIGURE 11: Comparison of solutions by bar charts

(a) Performance Indicators

It might be anticipated that the user may wish to examine the performance indicators of his latest trial and compare these with previous trials. At the most aggregated level the results are available in numeric form as shown in Figure 10. Here the results of two trials are shown, with the values of each indicator given for each planning period including the base year. Although useful, a direct comparison between the two results is difficult at first glance. To assist here, an alternative graphical comparison using a bar chart is available (see Figure 11). In this case up to 5 indicators (called active) can be selected for display. Each indicator takes one large bar with time progressing up the bar. So the 1980 results are at the bottom of each bar and the year 2000 results at the top. The base year result (1975 in this case) is shown by the vertical dotted line. In this way we can easily visualize the trends within each indicator (over time) and make direct comparisons between the two selected solutions (the left side and the right side). The set of indicators displayed and the scaling on the bar charts can be altered at any time by simple user command.

At this global level, the user may wish to complete some direct numerical comparison between solutions. For example, for the set of active indicators, the user can check all generated solutions for dominance. In this way we can find out which solutions are worse than (or equal to) some other solution for all of the set of active indicators. As the set of active performance indicators can easily be re-defined (or made to be just one indicator) this feature may well be useful for the user. Out of a set of solutions he can easily find the one which will be best for any selected indicator.

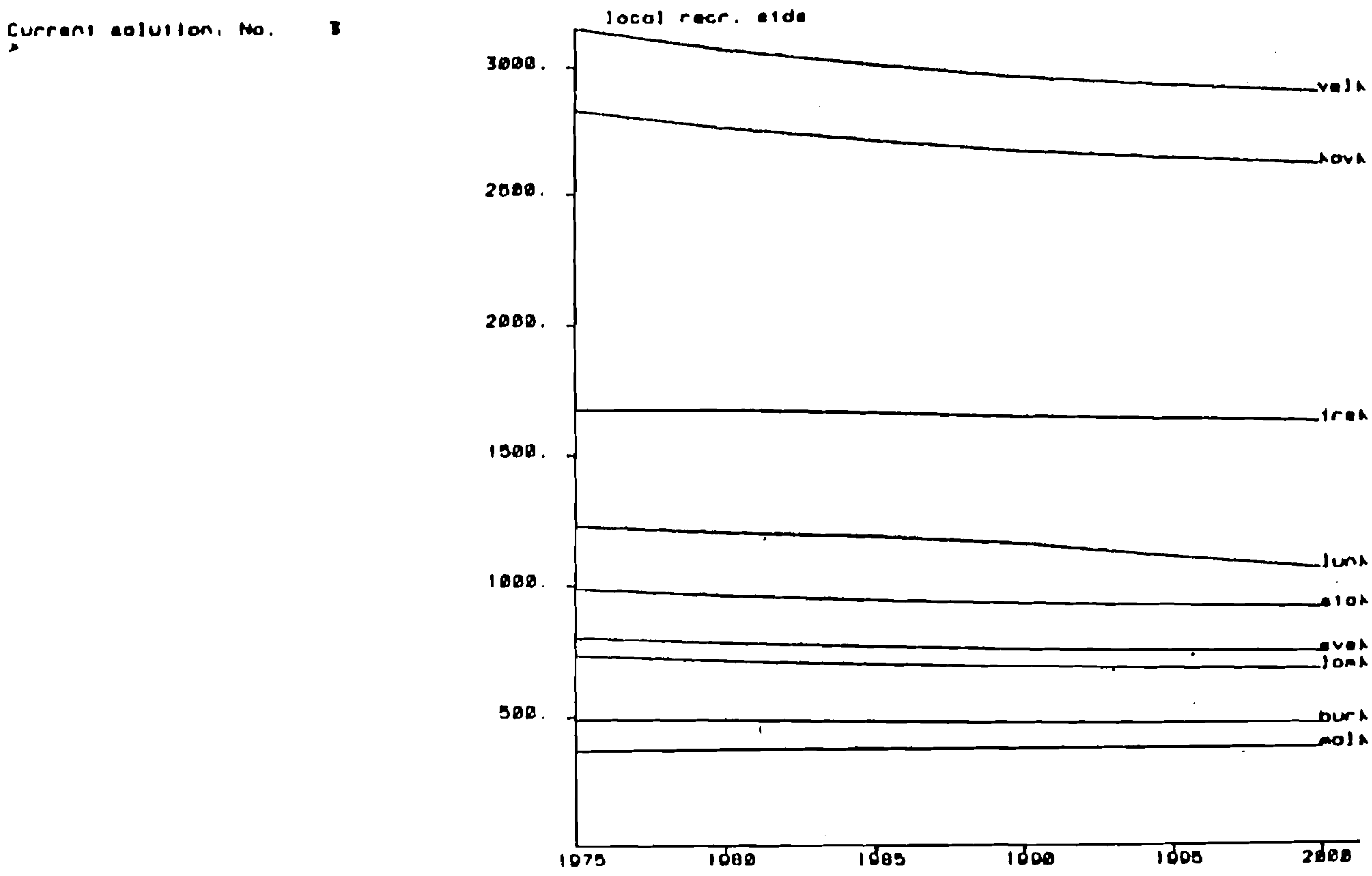

FIGURE 12: Plot of "local recreation standards" indicator at macro level

Current solution. No. 3

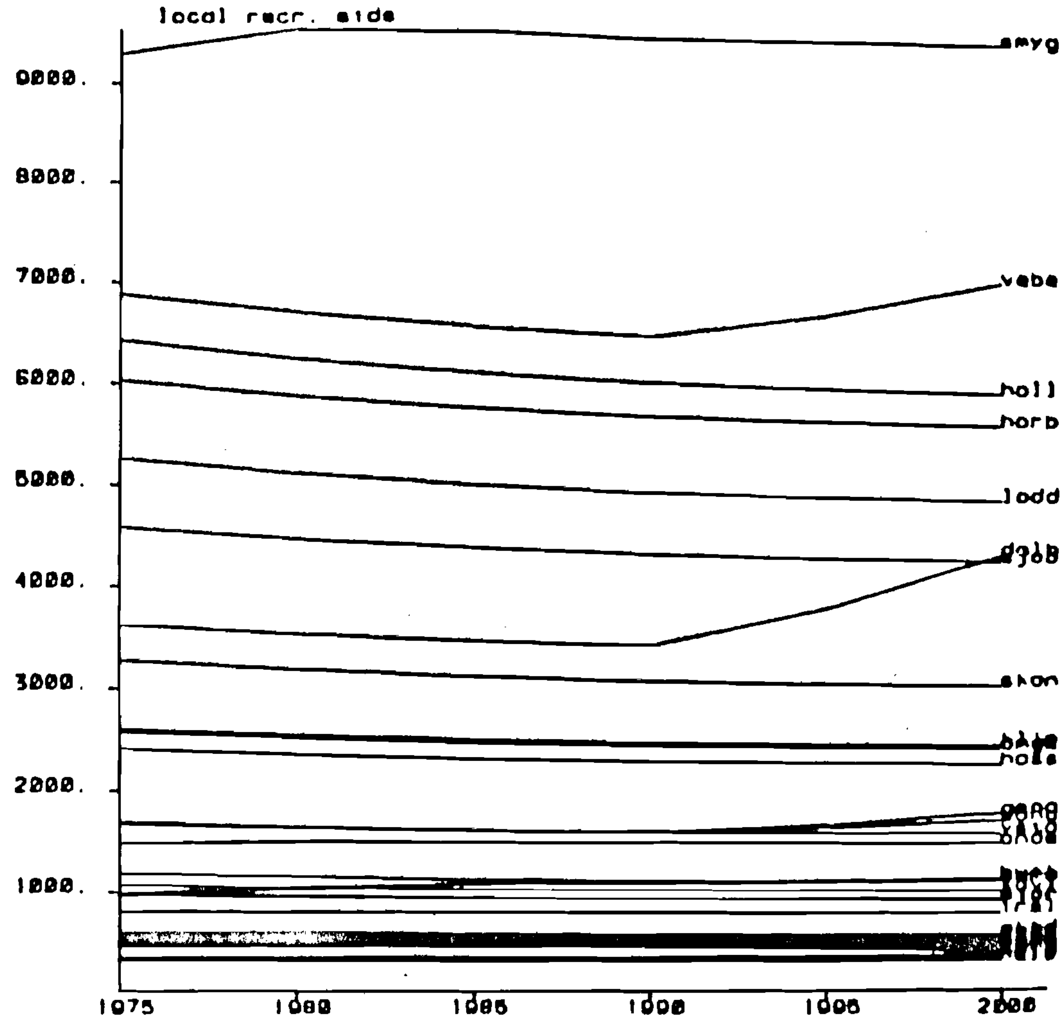

FIGURE 13: Plot of "local recreation standards" indicator at micro level

Since each performance indicator is evaluated at the macro and micro levels as well, these results are also available. The numerical results are available, if desired, but of more immediate use are the graphs as in Figures 12 and 13. Figure 12 shows the "local recreation standards" indicator from the Skåne study as it varies with time for each macro region (i.e. municipality). While Figure 13 shows the same indicator across the 35 sub-regions. Such graphs provide an immediate impact of the result and in particular, the variations amongst the macro and micro regions. To improve readability of such graphs selected sub-sets of regions can be displayed. Any of the performance indicators can be selected for display in this manner.

(b) The Forecast Micro State

The user will also be interested in examining various elements of the micro state. Tables showing the levels of each sector in a selected region or the values of a selected sector across all regions are available. For example, Figure 14 shows the value of each sector in the sub-region of Löddeköpinge for each time period. Such information is also available graphically, for example, Figure 15 shows the level of crop production (in employment) for each region with time. Figure 16 shows the same basic data, but now in terms of land area. In general, therefore, the user can selectively examine any sector across regions or any region for all sectors in terms of production or land consumed (at the micro level). The land consumed is also available in a spatial context as shown in Figure 17. Here we have plotted the sub-regions in the Municipality of Lund showing (selectively) the proportion of land used by single and multifamily housing, health and education.

Comparisons can be made directly between results from lodd

Region - lodd Production Values

	1980	1985	1990	1995	2000
crop	221.	198.	184.	169.	152.
meat	78.	71.	66.	61.	56.
vege	0.	0.	0.	0.	0.
fore	7.	7.	6.	6.	6.
food	628.	629.	629.	638.	648.
chem	119.	121.	123.	125.	128.
equi	243.	239.	241.	243.	245.
othe	825.	791.	785.	773.	761.
util	257.	261.	274.	281.	289.
petr	0.	0.	0.	0.	0.
whol	11	11.	11.	11.	11.
reta	66.	65.	64.	64.	63.
priv	194.	199.	204.	206.	208.
sing	7844.	8034.	8189.	8294.	8376.
mult	474.	477.	480.	481.	485.
educ	151.	168.	181.	183.	187.
heal	15.	18.	20.	21.	23.
publ	40.	49.	55.	59.	63.
road	0.	0.	0.	0.	0.
rail	0.	0.	0.	0.	0.
harb	0.	0.	0.	0.	0.
airp	0.	0.	0.	0.	0.
pers	11	12.	12.	12.	12.
good	10.	11.	11.	11.	11.
recr	425.	425.	425.	425.	425.
coas	363.	363.	363.	363.	363.

Current solution: No. 3

>

FIGURE 14: Table showing forecast micro sectors in sub-region of Loddekopinge

Current solution, No. 3

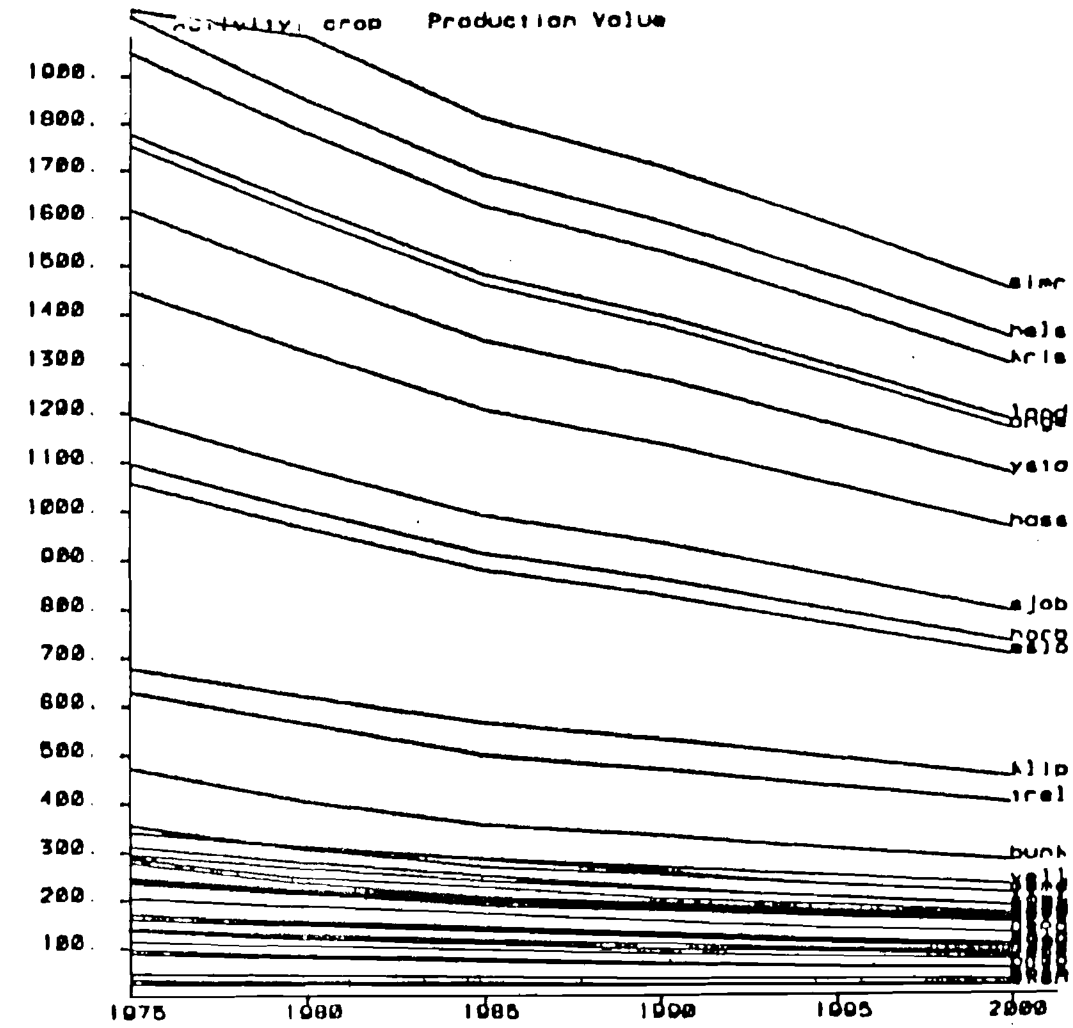

FIGURE 15: Plot of crop production (employment) in all sub-regions

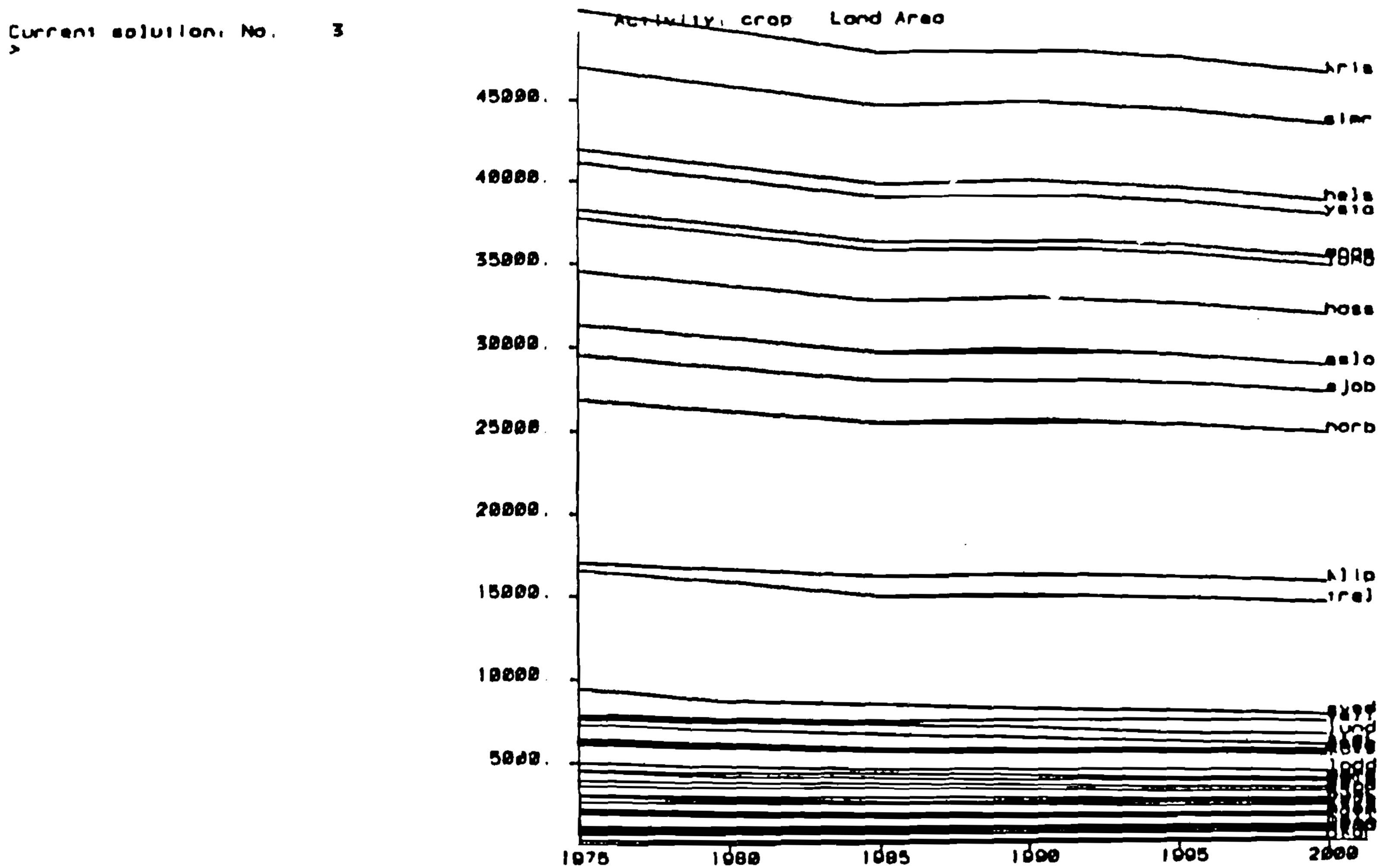

FIGURE 16: Plot of crop production (land areas) in all sub-regions

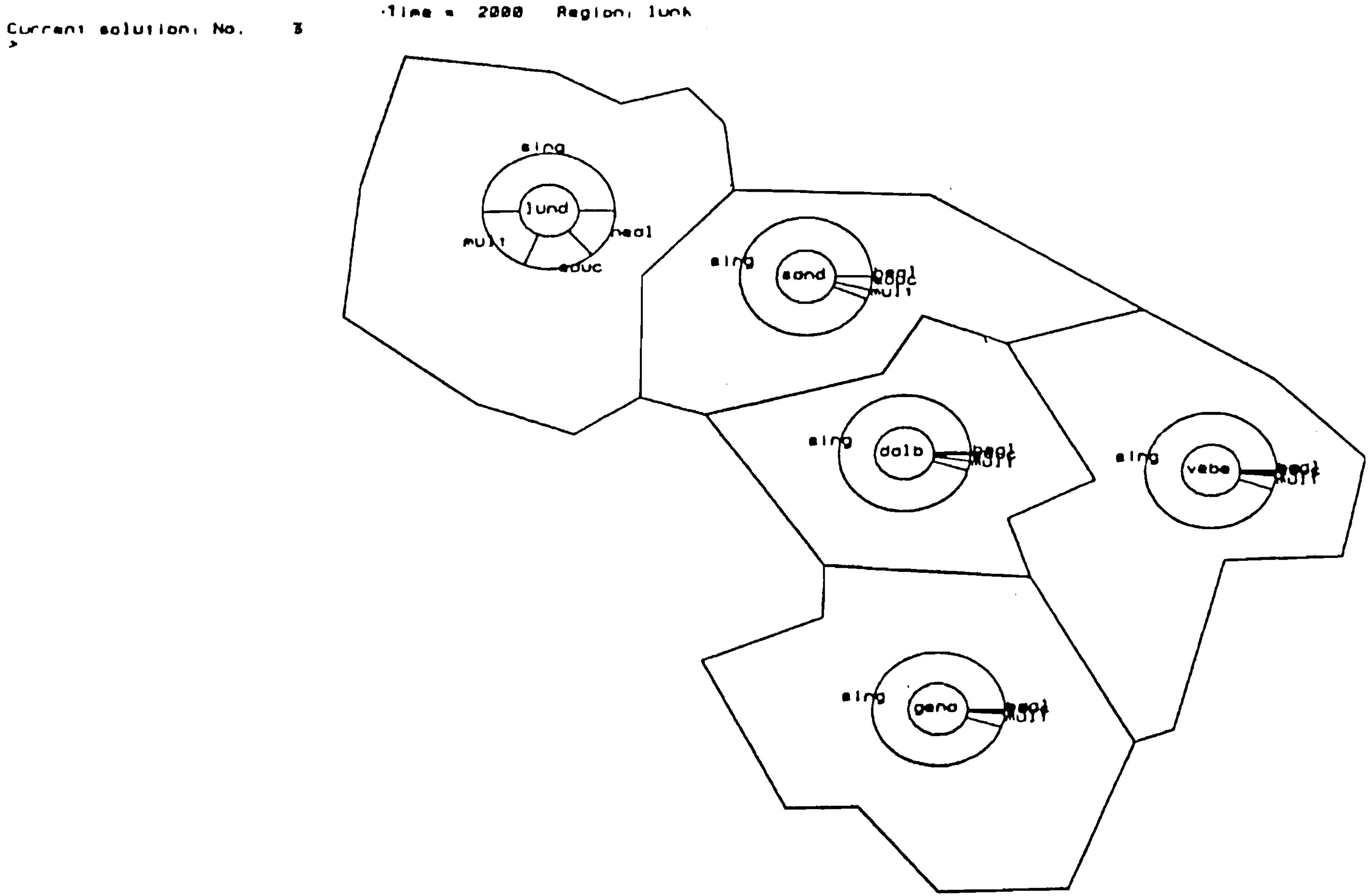

FIGURE 17: Plot of spatial distrubution of selected sectors in the Lund Kommun

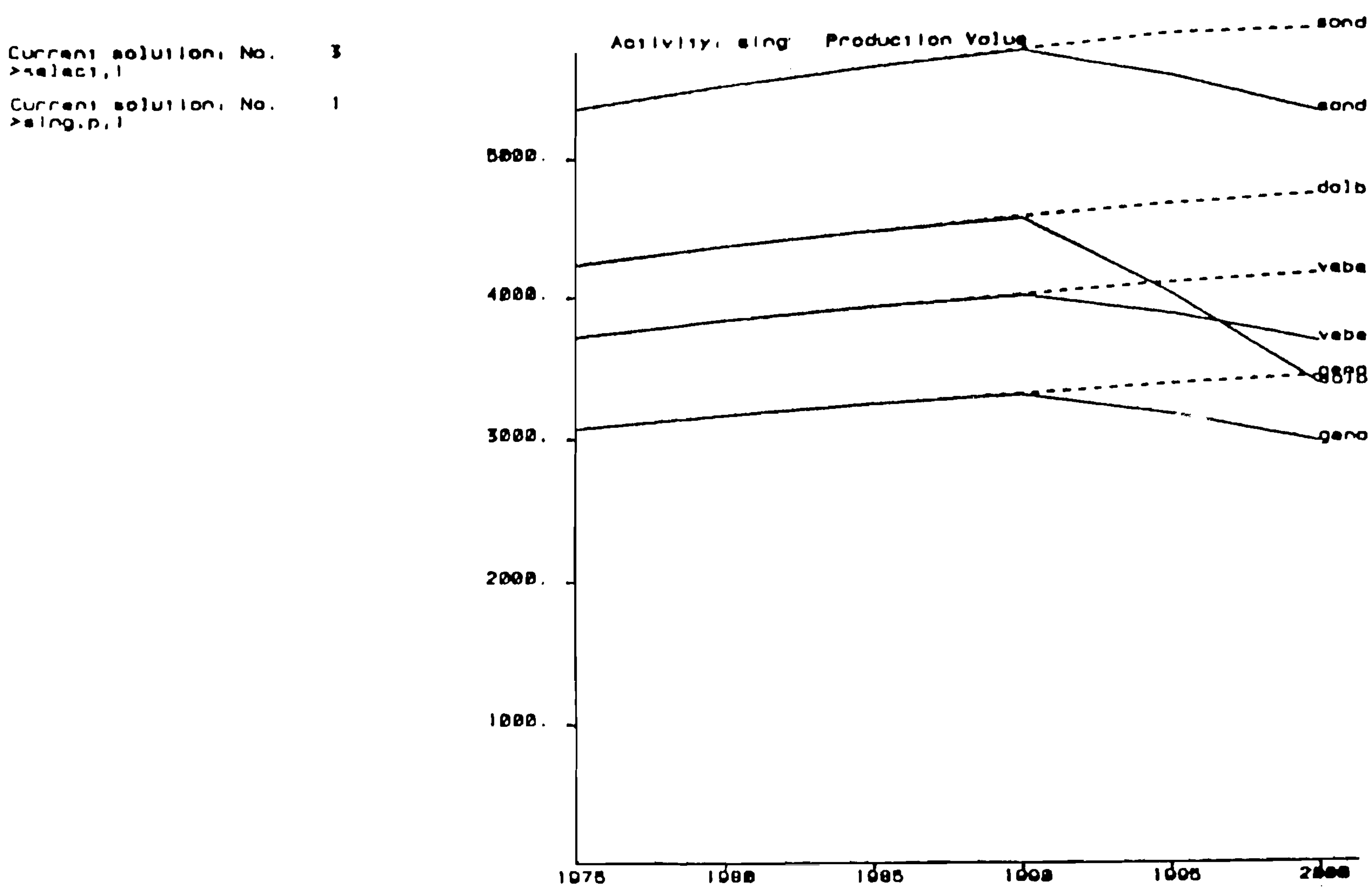

FIGURE 18: Plot showing comparison of two solutions for single family housing in selected sub-regions.

different trial solutions by plotting a second graph using dotted lines. Figure 18, shows an example for the value of single family housing (numbers of people) in a selected set of sub-regions plotted for two trial solutions.

(c) Constraint Deviations

Given that the user has imposed a set of special constraints to effect a planning policy, it may be of value to know which of the constraints had any real influence on the solutions obtained. This information is also available to the user though some care must be exercised in interpreting the results. For the several sets of constraints which are included in the ISP model (including the special user defined constraints), the constraint deviations are available. The constraint deviations are the differences between the left and right hand sides. So for an equality constraint we should always expect a zero deviation.

For a selected time period the user can request a print-out of the constraint deviations for any sub-set of constraints in the ISP model. Figure 19 shows an example for the deviations in the macro land constraints (i.e. the differences between the land allocated and that actually used at the macro level) and the user defined special constraints. Figure 20 shows deviations for the region wide production constraints and the region land area constraints.

To assist in the display of data and operation of the reporting phase several other features are included. For example, Figure 21 shows the "display" Table which defines which sectors and/or regions are actually displayed in the graphical presentations. The user has access to this Table and by means of simple commands can make active (or inactive) any sector,

```
devl,m,1990

Constraint deviations for 1990
Macro land constraints-
      kovk   lomk   lunk   stak   burk   malk   svek   velk   trek   rout

agrb     1.     0.     1.     1.     0.     1.     1.  -758.     3.   -12.
indb     0.    -0.     0.    -1.    -7.     0.    -2.    -2.    -0.   -25.
eneb    -0.    -0.    -0.    -1.    -0.    -0.    -1.    -3.    -1.   -16.
serb    -1.    -2.    -4.    -2.    -9.     0.  -156.    -1.   -33.   -34.
houb   -21.   -15.     0.   -35.    -5.     0.   -41.   -22.     0.     0.
govb    -7.     0.     0.   -20.    -0.     0.    -4.     0.     0.  -136.
slab    -0.    -0.     0.     0.    -0.    -1.     0.    -1.    -1.    -0.

Current solution, No.     2
>devi,s,1990

Constraint deviations for 1990
Special constraints-
sing lund(<),       0.
sing malm(<),    3740.
sing stof(>),       0.
sing staf /mult stof(<),      0.
Current solution, No.     2
>
```

FIGURE 19: Table of constraint deviations for macro land and special constraints

```
devi,p,1990

Constraint deviations for 1990
Production constraints-
crop:      0.  meat:      0.  vege:      0.  fore:     -0.  food:     -0.
chem:     -0.  equi:      0.  othe:      0.  util:      0.  petr:      0.
whol:      0.  reta:      0.  priv:      0.  sing:     -0.  mult:     -0.
educ:      0.  heal:      0.  publ:      0.  road:      0.  rail:      0.
horb:      0.  airp:     -0.  pers:      0.  good:      0.  recr:      0.
coos:      0.
Current solution: No.     2
>devi,l,1990

Constraint deviations for 1990
Land area constraints-
lodd:  -1308.  kavl:  -1121.  bjor:   -396.  lomm:   -230.  lund:  -1495.
sand:  -3014.  dalb:  -2267.  geno:  -1857.  vebe:  -2976.  hjor:   -285.
staf:  -1577.  akar:    -18.  arlo:   -367.  malm:  -1710.  oxle:   -475.
bunk:   -880.  bara:  -2199.  sved:  -2803.  vell:  -1138.  hall:   -560.
skan:   -335.  ande:  -1456.  smyg:   -708.  trel:  -2297.  hels:  -7468.
land:  -3711.  eslo:  -5258.  sjob:  -8759.  ysto:  -7011.  onge: -13135.
klip: -17637.  hoss: -51356.  horb: -16013.  kris: -37042.  simr: -12413.

Current solution: No.     2
>
```

FIGURE 20: Tables of constraint deviations for region wide production and region land area constraints.

```
1

List of active activities & regions (1-active, 0-inactive)
Micro variables
crop(1) meat(1) vege(1) fore(1) food(1)
chem(1) equi(1) othe(1) util(1) petr(1)
whol(1) reta(1) priv(1) sing(1) mult(1)
educ(1) heal(1) publ(1) road(1) rail(1)
harb(1) airp(1) pers(1) good(1) recr(1)
coas(1)
Macro variables
agrb(0) indb(1) eneb(1) serb(1) houb(1)
govb(1) slob(0)
Micro regions
lodd(1) kavl(1) bjar(1) lomm(1) lund(1)
sand(1) dalb(1) gena(1) vebe(1) hjar(1)
stof(1) okar(1) arlo(1) malm(1) oxie(1)
bunk(1) bara(1) sved(1) vell(1) holl(1)
skan(1) ande(1) smyg(1) trel(1) hels(1)
land(1) eslo(1) sjob(1) ysta(1) onge(1)
klip(1) hoss(1) horb(1) kris(1) simr(1)

Macro regions
kavk(1) lomk(1) lunk(1) stok(1) burk(1)
malk(1) svek(1) velk(1) trek(1) rout(1)

*
```

FIGURE 21: Display table

```
list

Index of results file
     1. Base solution as prepared by F. Snickars and G. G. Roy at IIASA
     2. Housing limited in Malmö & Lund, increase multi housing in Stof.
     3. Trial to increase single family housing in Lund
Current solution: No.     3
>
```

FIGURE 22: Example index of results file for all solutions so far generated

region, group of sectors and group of regions. Also, as each trial solution is generated an index is updated so that the user can see at a glance a brief report on what solutions he has so far generated (see Figure 22).

Phase 4 of the ISP system can be used simply to report from and compare solutions already generated. There is no need to generate new solutions each time the system is accessed.

4.6 Phase 5: Documentation Phase

It will always be necessary to prepare detailed reports of selected trial solutions. Such reports can be prepared on the line printer. Currently, this facility is available by a separate program (REPORT) which allows the user to select the type(s) of reports required and which trials he wants to be reported from. Figure 23 shows and example run of REPORT. The reports basically show the values of each sector in each region by both production value and land area. All combinations of aggregation are possible. Also the values of the objectives (performance indicators) at micro, macro and global levels are available.

If desired, the user can also obtain a detailed report of all constraint characteristics which includes, right hand side value, deviations and the value of dual variables.

5. OPERATIONAL ENVIRONMENT

5.1 User Commands

The operation of the ISP system is controlled by user commands. These are typically single character or four character (English language) mnemonics. To prompt the user

```
Save print out on disk (y/n) :n

Output options -
     1 - User defined macro allocation of land
     2 - Macro sectors in Macro regions
     3 - Macro sectors in Micro regions
     4 - Micro sectors in Macro regions
     5 - Micro sectors in Micro regions
     6 - Total Production values
     7 - Objectives
     8 - Constraint characteristics
     9 - All above
:1,3,7,8

Input list of trials to be reported (max 20)
:1

     1: Base solution as prepared by GGR & FS at IIASA for SSK
Input Constraints file name: base.con
```

FIGURE 23: Example run of REPORT program

(beginner) at each phase a "h" (for help) command at any stage will give a list of appropriate commands for that stage. In general only a single level of commands is used. Commands are often followed by a set of arguments which are used to qualify the command. Figures 24a, b, c and d show the "help" files at each of the 4 interactive phases of the ISP system. Currently two commands in the Reporting Phase require a second command level. In each case "help" files are available for each, see Figures 25a and b. Detailed descriptions of each command is given in the ISP User Manual. A brief summary of the commands available is given in the Appendix to this report.

In addition to the defined command mnemonics, the user must choose a set of four character descriptions to define the sectors and regions at both macro and micro levels. These descriptions must all be unique and different from the system dependent commands. Throughout the operation of ISP the user will use these descriptions for reference to the sector or region required. In addition, certain descriptions are assumed to include all of a particular set of characteristics allowing the user to often include whole sets of sectors, regions and time periods into a single command. This feature is particularly useful when defining sets of special constraints.

5.2 Convergence and User Learning

Any one trial solution must be viewed as an experiment. The response of the user to the results of that trial means that the user has learned something of the character of his region. The ISP model is so structured that the user can easily return to Phases 1 and 2 to add/change specific planning policies in an endeavour to improve the results in the next trial solution. Initially this cyclic process may be

```
Allocation phase
:h

HELP message for ALLOCATION phase -
c - continue to SPECIAL CONSTRAINTS phase
v - verify macro land allocation
d - display table of land allocation
n - step to next time period
b - go back to previous time period
m - modify element in allocation
g - graph allocation
i - ignore errors when stepping to next time period
s - save macro land allocation on disk
r - read new macro land allocation from disk
:c
```

FIGURE 24a: Help file for Allocation phase

```
Special constraint phase -
>h

HELP message for SPECIAL CONSTRAINTS phase -
cont - continue on to SOLUTION phase
list - list special constraints
back - go back to ALLOCATION phase
save - save special constraints on disk
read - read special constraints from disk
wipe - remove sets of special constraints
help - type this message
adds - to add single variable constraints
addr - to add ratio of two variables constraints
addb - to add bound type constraint
addm - to add macro variable contraint
mods - to modify single variable constraint
modr - to modify ratio type constraint
modb - to modify bound type constraint
modm - to modify macro variable constraint
>cont
```

FIGURE 24b: Help file for Special Constraint phase

```
Solution phase:
>help

HELP message for SOLUTION phase -
cont - continue to solve
skip - skip to REPORTING phase
help - type this message
>cont
```

FIGURE 24c: Help file for Solution phase

```
Reporting phase
Current solution: No.     1
>h

HELP message for REPORTING phase -
cont - continue on to ALLOCATION phase
exit - to terminate program
show - to examine objectives
select - to select a solution for reporting
rest - to restore macro land allocation from selected solution
nond - to list non-dominated solutions
disp - to examine/modify display table
devi - to examine constraint deviations and modify macro land
list - lists solutions in RESULT file
help - type this message
**** - refer to manual for commands to list/graph data
Current solution: No.     1
>disp
```

FIGURE 24d: Help file for Reporting phase

```
*h

HELP message for 'disp' command
i - insert sector/region
d - delete sector/region
l - list display table
r - restore all regions and sectors to active
z - remove all sectors and regions
c - to return to main command level
h - type this message
*
```

FIGURE 25a: Help file for "disp" command

```
Current solution: No.     1
>show,s

*h

HELP message for 'show,s' command
l - lists objective definitions
d - to make objective inactive
a - to activate objective
m - to modify characteristics
c - to return to main command level
h - type this message
*
```

FIGURE 25b: Help file for "show,s" command rather undirected and random, but it is anticipated that as the user's experience grows, he will be able to make more consistent adjustments to his planning policies.

There is no specific aids in the system to direct the user in any particular direction at the moment. In the future some help here may be possible (see Section 6). We are very conscious, however, to avoid making value judgements within the model. The changes a user will make to seek a change in balance or trade-off amongst the performance indicators is highly subjective. We believe that the user should make those judgements. The ease in which new planning policies can be formulated in the model and evaluated should assist a great deal in providing a suitable learning environment for the prospective user. We do expect, however, that in the initial stages many trivial and or rather useless trials may be generated, but this must be accepted as a part of the learning process.

Over a period of time the user should aim to develop a small set of "good" solutions which may need much more detailed evaluation before any specific planning policy is to be implemented. In fact we do not see the ISP system as a means of deriving a single "ideal" planning scheme, but rather a mechanism to generate and test alternative policies.

6. FUTURE PROSPECTS

The current state of development of the ISP system does ignore some major elements in the modelling of regional systems. Given some continued support and interest in the system it is intended that these areas be implemented. The major elements are as follows:

(a) Transportation

Currently no formal inclusion is allowed for the transportation network and transportation flows (commuting, etc.). It is intended that a sub-model be developed and included so that the relationships between land use and the transportation system can be explicitly included. This will mean that the given, and projected, network will be able to constrain the allocation of land so that no linkages in the network exceed their defined capacities. It is not intended that this sub-model will be a fully fledged transportation model, but instead a simplified one.

(b) Renewable Resources

Resources such as energy, water, finance can all place constraints on development. We plan to develop suitable sub-models to handle these characteristics so that land use allocations stay within the levels of the demand for various types of renewable resources.

(c) Data Base Management

To date little effort has been spent on the requirements to update and maintain the data bases required by the ISP system. Some additional work is required in this area to enable users to correct data, make changes to basic data elements and to generally maintain the complete set of data.

(d) Graphical Displays

Although the graphic presentations are now operational there will always be a need to refine or reformat certain types of display. We would also welcome the opportunity to further extend the graphical capabilities with colour graphics.

(e) Complex Special Constraints

It is planned to incorporate more complex forms of special constraints to allow the user more flexibility to express planning policies in particular the single variable and ratio type constraints will be enhanced to include a summation of terms on the left hand sides.

(f) Efficiency of Solutions

Currently no specific guidance is given to the user as to the efficiency, or otherwise, of any solution except from direct comparisons with solutions already generated. We would like to be able to include the facility to generate upper and lower bounds for each performance indicator by optimizing each individually. Such a proposal generates complex problems, but within certain limits it should be possible for at least some of the performance indicators. Any generated solution could then be compared with this data to give the user some idea of whether he should expect significant improvements in any indicator.

REFERENCES

1. Roy, G.G. and Snickars, F. (1981), "An Interactive Computer Model for Land Allocation in Regional Planning, Part 1: Theoretical Foundations and Operational Principles". WP-81-00. I.I.A.S.A., Austria (forthcoming).

2. Roy, G.G. and Snickars, F. (1981), "ISP-A New Approach to Land use Planning", Conference on Projection Methods, Swedish National Association of Planners and Statisticians, Malmö, Sweden, May.

3. Roy, G.G. (1981a), "An Interactive Computer Model for Land Allocation in Regional Planning, Part 2: System Design and User Manual". WP-81-47. I.I.A.S.A., Austria,

4. Roy, G.G. (1981b), "ISP User Manual", School of Architecture, University of Western Australia.

APPENDIX: SUMMARY OF COMMANDS

1. Definitions

Alternative arguments are shown in {..} and optional arguments are shown in [..]. The following arguments have the meanings indicated:

micv: means any valid micro variable name and includes "vall"

micr: means any valid micro region name and includes "rall"

macv: means any valid macro variable name and includes "valm"

macr: means any valid macro region name and includes "ralm", "rout" and "rext"

time: means any valid year label including "0"

value: means any valid numeric value

k,kl,k2:mean an an integer value

file: means a valid disk file name (up to 10 characters)

<cr>: means a "carriage return"

2. Phase 1 Commands: Macro Allocation of Land

c	continue to Phase 2
d	display tablle of allocation
v	verify allocation
n	step to next time
b	go back to previous time
g	plot map of macro allocation
g,{macv,macr},[l]	plot graph of macro allocation versus time
m,macv,macr,value	modify element in macro allocation
s	save on disk file current macro land allocation
r	read from disk file new macro land allocation
i	ignore inconsistencies
h	list commands

3. Phase 2: Special Constraints

```
cont                continue to Phase 3
back                go back to Phase 1
list,[m,k]          list sets of special constraints
wipe,{s,r,b,m,a}    remove sets of special constraints
save                save on disk constraint data
read                read from disk constraint data
adds<cr>
micv,micr,time,{<,=,>,*}value
                    add single variable type constraint
mods<cr>
micv,micr,time,{<,=,>,*}value,[{r,i}],[k]
                    modify single variable type
                    constraint
addr<cr>
micv,micr,time,/
micv,micr,time,{<,=,>,*}value
                    add ratio type constraint
modr<cr>
micv,micr,time,/
micv,micr,time,{<,=,>,*}value,[r,k]
                    modify ratio type constraint
addb<cr>
micv,micr,time,{<,=,>,*}value
                    add bound type constraint
modb<cr>
micv,micr,time,{<,=,>,*}value,[r,k]
                    modify bound type constraint
addm<cr>
macv,macr,time,{<,=,>,*}
                    add macro land constraint
modm<cr>
macv,macr,time,{<,=,>,*}
                    modify macro land constraint
help                prints list of commands
```

4. Phase 3: Solution of Problem

```
cont                continue and solve problem
skip                go straight to Phase 4 without
                    solving problem
help                list commands
```

5. PHase 4: Reporting Phase

```
cont                return to Phase 1
exit                terminate ISP
select,[k]          select a new solution for reporting
rest                replace current macro allocation
```

```
                    with that one from the currently
                    selected solution
nond                list non-dominated solutions
show,[{m,i}],[{time,k1}],[l]
                    to examine objectives by graph or
                    tabular presentation
show,c,k1,k2        to compare any two solutions by
                    bar chart
show,s<cr>
{l,d,a,m,h,c},[k],[val1,val2],[{min,max}]
                    to examine/modify objective
                    characteristics
rall,g,time         to plot map of all macro regions
                    showing macro land uses
{macv,macr},g,[l] to plot graph of macro land
                    uses versus time
{micv,micr},[{p,l}],[{1,-1}]
                    to display micro solution by
                    graph or table
{macr},g,time       to plot map of macro region
                    showing micro land uses in
                    micro regions
devi,{f,p,l,m,s,r,},[time]
                    examine constraint characteristics
disp<cr>
{i,d,l,c,r,z,h},[{micv,micr,macv,macr}],...
                    to examine/modify the display table
list                list index of solutions on
                    results file
help                list commands
```