MURCIA A/I, A MIXED SYSTEM DYNAMICS AND LINEAR PROGRAMMING MODEL FOR REGIONAL INVESTMENT PLANNING .

Toval, A.[1]; Requena, A.[1]; Martínez, S.[3]; Monreal,J.[2]

(1) Escuela Universitaria de Informática. Universidad de Murcia
(2) Facultad de C. Económicas. Universidad de Murcia
(3) Instituto de Economía Agraria y Desarrollo Rural. Consejo de Investigaciones Científicas (CSIC). Madrid.

Abstract. When distribution of economic goods, equipments,... takes place among different regions, it is expected to carry out / in an optimal way, considering "optimal" the way of distribution that assigns more to the neediest regions; thus, numerous fac- / tors such as economic conditions, actual equipments, social conditions, population, etc, should be taken into account.
The presented model has a double aim: firstly to show the pre- / sent behaviour of distribution system of investment in Comunidad Autonoma de Murcia, regionally, and secondly to get this distribution to optimize a linear function that represents the regional social welfare as a consequence of the social welfare in / each region of the Community and dependent on linear constraints To reach these objectives, a mixed model that combines both System Dynamics and Linear Programming techniques is constructed ; a relation between both procedures is established in order to simulate both the natural behaviour of the distribution system and those decisions that make this distribution to be optimal.
Along this report the method carried out to handle mixed models/ as well as the particular model MURCIA A/I are described.

INTRODUCTION

In last years a centrifugal process is carrying in the structure of the Administration of Spain and the Regional governments taking actions to know the changing conditions and to improve the dynamics of the economical and social activities.

This paper takes part of an initial study of the Comunidad Autonoma de Murcia to establish an optimal way to assign the investment. The scope of the work is centered in the use of the System Dynamics methodology combined with the Linear Programming procedures in order to produce a simulation of the behaviour of a distribution system, in which the gap of the several factors determining the "necessity" is minimized.

In traditional dynamics systems simulation, various types of variables are handled in order to understand the behaviour of the systems by means of the behaviour of the variables along the horizon time. This behaviour is usually depicted trough mathematical functions which depend on either other system variables, previous values of the same variable or constants.

As it is known, to build a system dynamics model it is necessary to find the mathematical relationships or functions able to describe the real behaviour of the system.

In this way, the "natural" behaviour can be modelled. However, / sometimes, when we are working with some specific kind of sys- / tems, simulation or modelling of the natural behaviour of the / system may be not enough, because besides to the natural it may be interesting, or necessary, to simulate the decision-making of the managers, based on environmental factors, state of the sys-- tem or policy constraints, in each timestep.

Several examples of this kind of systems have been already studied by the authors; those belong to areas so different as:

Farming policy, Toval,A.(1985), Labor-Market, or which we describe below, about regional investment planning, MURCIA A/I.

Section II includes a formulation of System Dynamics and Linear/ Programming mixed models and section III relates the Assignement Investment Murcia model including numerical results for various/ hypothesis.

SYSTEM DYNAMICS AND LINEAR PROGRAMMING (SD-LP) MODELS

The aim of SD-LP models is to incorporate the simulation of decision-making, when this is carried out trough one or several linear programs, into the traditional system dynamics techniques . Thus, it is possible to obtain the optimal values of the system/ variables which participate as an objective function or as activities in some previously defined linear program, so making po-- ssible the simulation of decision-making at each time of the run

Althought the method is shown to use only linear programming, / there is no problem to apply it to non-linear programming pro- / blems using the same SD-LP algorithm (fig.1) and the same interfaces to the sistem dynamics equations with minor changes.

To simplify, let us assume that we have defined an unique linear program together with the system dynamics equations, althought / we could consider as many as we wish, with the only limitation / of the memory computer size.

The objective consists in simulating the optimal behaviour of a variable and, in consequence, the corresponding values for those variables which participate as activites in the definition of / that variable.

With this purpose, let us fistly consider the usual linear pro-- gramming form:

$$\text{(optimize)} \quad z = c'x \qquad (1)$$

$$\text{subject to:} \quad A1\ x \leq b1$$
$$A2\ x = b2$$
$$A3\ x \geq b3$$

using matrix form.

We call SD-LP model to the system dynamics one embodying one or / several linear programs which have the following characteristics: the coefficients for the vectors c, b and matrix A, are not obli-- ged to be constant, as it is usual in linear programming problems but they can be time-depending functions defined in relation to / the elements of the system to be modelled. Thus, the usual SD-LP / model is posed as:

$$\begin{aligned} &\text{(optimize)} \quad z(t) = c'(t)\, x(t) \qquad (2) \\ &\text{subject to} \quad A1(t)\, x(t) \leq b1(t) \\ &\qquad\qquad\quad A2(t)\, x(t) = b2(t) \\ &\qquad\qquad\quad A3(t)\, x(t) \geq b3(t) \end{aligned}$$

Some of the coefficients of A, b or c may be constant (constant / functions) if necessary. We can distinguish two kind of taking / part in SD_LP models:

SD	LP
Levels	Cost coefficients(c)
Rates	Constraints or technological coefficients(A)
Auxiliaries	Activity variables (x)
Exogenous	Resources coefficients(b)
Constants	Objective function variables (z)

Note that many of the LP-coefficients are included into SD one / although it may ocurrs that we use some LP-coefficients exclusively in the linear program, without any interest since the system / modelling vewpoint.

In this case, they can be performed as auxiliaries or merely as / computer programming variables non essential for the model.

When we pose a linear program in this "dynamic" way,(2), we can consider that during an iteration, t, coefficients of c(t), A(t), and b(t), remain constant and so we can operate the linear pro- / gram, in that moment, as an usual one (1), and we can to apply / the simplex or revised simplex algorithm for the actual constant/ values. At the next iteration, t+1, the values of the coefficients c(t), A(t) and b(t) will be changed, but during the current t+1 / iteration, they will again remain constant and we'll can again a- pply the same procedure to solve the linear program posed in this time and so on.

Before the run begins, we should give to the model the initial values of c(0), b(0) and A(0), which will be either fictitious values for those functions which are not constant, or the real values for the functions being really constant along the time horizon.

Thus, we have defined a dynamic linear program which is different each timestep of the run because its coefficients are changed. However, the structure of the linear program will remain unchanged , except if at some iteration we add or substract activities (x) or constraints to it, although we seldom will do this.

As a consequence of the simplex run, we'll can obtaint, each timestep the optimal values of the variables which participate either as an objective function or as decision variables. This fact in-- corporates to the system dynamics model the ability to simulate / the making decisions at each timestep as well as the results of applying these decisions, bearing in mind the environment chan- / ging conditions.

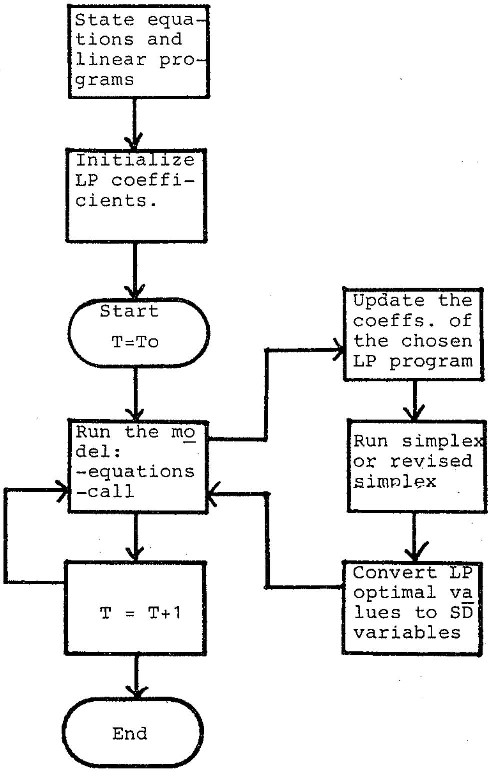


Fig. 1 Algorithm to operate SD-LP models

Figure 1 shows the steps of the algorithm of operating SD-LP models.

To finish this section, we are going to give a warning: is necessary to bear in mind that as the linear program coefficients / values change, even randomly, it can be produced, at a certain / timestep, a linear program which cannot be solved because it may not exist either an optimal or a feasible solution. If some problem of this kind occurs, it could be a reason some of the following:

- The model (as a set of equations and linear programs) has inaccurately been posed.
- The chosen scenario is inadequate.
- The system will really reach a state where it will not be possible to make an optimal decision according to the posed linear program.

It is advisable to provide an alternative solution to prevent / this event.

It is advisable too, the using of linear programming sensitivity methods to be able to use the optimal solutions reached at the / previous timestep, t-1, in order to make decrease the number of iterations of the simplex algorithm, to compute in a few time, / the optimal solution at the present time, t, and so on. These / methods are well known in operations research and they can be applied when some of the linear program "data" vary. Changes can be made in:

- b vector (resources) values
- c vector (costs) values
- A matrix (technological coefficients) values
- x vector (activities or decision variables) values
- the number of activities or decision variables
- the number of constraints

Study of the variation of the solution with the variation of some coefficients is not difficult, the last two variations are a more intrincate matter.

Note that the last two kind of changes involve changes in the / structure of the initial linear program, what will not be usual/ but provides more flexibility to these models. Procedures to program these methods can be found in Prawda(1982), Sakarovitch / (1983) and many other books about linear programming.

MURCIA A/I MODEL FORMULATION

Murcia A/I model has been designed to provide a tool to assist in decision-making to the "Consejeria de Políticia Territorial (CPT)" (Department of Territorial Policy) of the Comunidad Autonoma in Murcia in Spain, about the distribution of investment in the community. This distribution will be carried out bearing in mind / the twelve regions wchich constitute the community of Murcia.(See Appendix I)
Figure 2 shows the hierarchy of the organs of government over the community of Murcia including the Central spanish government.

There are five basic aspects to distribute the investment, in order to

1) Decrease the differences between the regions about the following eleven equipments goods and infrastructures: transportation, housing, urban planning, supply, road network maintenance, road network improvements, ports, river edges and irrigation channels, public health, water depuration and environment.

2) Guarantee the minimum investment according to the weight of / the regional population with respect to the total population / in the community.

3) Guarantee the minimum investment according to the region geographic size.

4) Maximize a regional welfare index either using linear programming, when possible, or unless, an equation as the European / Social Fund does.

Description of model components

Murcia A/I model, or simply A/I model, uses about 600 variables , 500 constants, 11 tables and 500 equations. This is the reason / because we´ll merely describe the most important relationships / and the general aspects of it. For further details about the model, and software used to run it, the readers may look up Murcia/ A/I (1986).

From a geographical viewpoint, the model is thought of two levels: the upper one, or aggregate, which is constituted by the / global community and the lower one, or disaggregate, which is / constituted by the twelve regions.

The advisable time horizon is the period of three years, making / corrections every month and every year in the data set. However , the model is run for the period 1983-1986 because of the available data.

Figure 3 shows a very simplified loop diagram of the model A/I . The four major submodels are: Population, Labor, Aggregative economics and Distribution of CPT-investment.

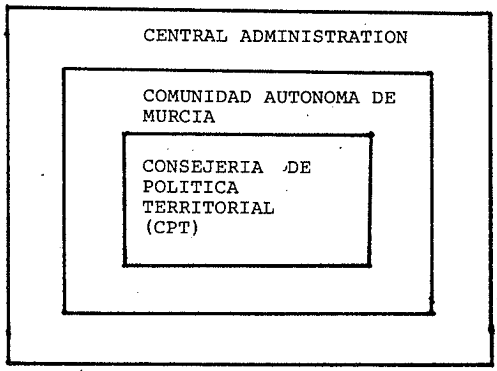


Fig. 2 Hierarchy of the organs of government

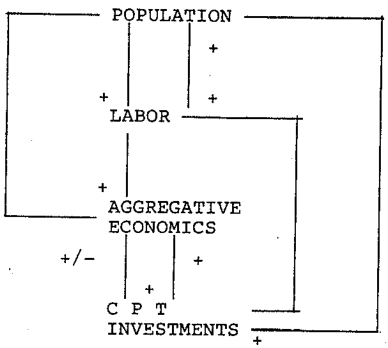


Fig. 3 A/I Simplified causal diagram

Each one of these, includes variables which belong either to the aggregate or to the disaggregate level.

A) Population model (regional and community)

- The vegetative growing depends on the difference between the / birth and death rates
- Migrations are obtained by means of an equation describing the statistics behaviour of them, which includes three aspects: average familiy size, unemployment (with a certain delay structure) and the growth rate of the regional per capita income.

B) Labor model (regional and community)

- Regional active population is obtained by multiplying the activity index by the corresponding population.
- Once we have got the community active population, by adding / the regional one, active population per major sectors (fourth) are computed by fractions obtained from an Active Population / Sampling.
- The difference between active population and available jobs determines the employment level per each major sector, respectively.
- Employment net variations, per major sectors, depend on stochastic equations, which are based on the following causes: / previous new jobs, Lq coefficient of population variation, total employment variation, irrigated land variation and industrial land variation.
- Regional unemployment is determined by the difference between/ the active population and the total employment. The recorded / historical unemployment data, by extrapolating, determine the youthful unemployment.

C) Aggregative economics model (regional and community)

At the upper level (community) the economic network is modeled . The essential relationships are:

- Foreign, Comunidad Autonoma, Business and Central Administration investments are exogenous. Comunidad Autonoma investment/ should specially be simulated.
- CPT investment is computed as a fraction of Comunidad Autónoma investment. This fraction will be one of the basic parameter / to simulate the system.
- Inner private investment is assumed to be equal to the inner / saving. Also the inner saving depends both on the regional income and the per capita income.

- The distribution of the total investment per the fourth major sectors is one of the main aim of the model. The functions to distribute the investment are the following:

IA = FUNCTION(IA/II, EXA/EX, TEA/TE)

IC = FUNCTION(IC/IT, TEC/TE) (3)

II = FUNCTION(II/IT, EXI/EX, TEI/TE)

IS = IT- IA- IC - II

the meaning of the variables is

IA: Agriculture investment
IC: Building "
II: Industry "
IS: Services "
IT: Total "
EXA:Agricultural exports
EXI:Industrial exports
EX :Total exports
TEA:Agrarian employment level
TEC:Building " "
TEI:Industry " "
TES:Services " "
TE :Total " "

- The investment is converted to production by means of the fraction ICOR(Incremental capital-output relation) using the relations:

ICORA = DPA/IA ICORC = DPC/IC ICORI = DPI/II ICORS $= \frac{DPS}{IS}$

ICOR(X) means the fraction ICOR per each of the major sectors / and DP(X) means the increment of production. Note that these increments may, possibly, be negative.

- The total production per major sectors (defined as the gross / added value) is obtained by adding the increments per year to/ the previous production. In this way, the productions per sector are rate variables, but they work as level variables and in this manner is as we are going to operate with them (from a system dynamics viewpoint).

- The total employment per sector is computed by dividing the / sector productions by the corresponding average productivity.

- Community income depends on the sum of the sector gross added/ values, computed as the net added value and it is added to the remaining income originated by the CPT investment. Per capita/ income is computed from the regional income previously defi- / ned.

D) Consejería de Política Territorial (CPT) investments

This model is the main subject and the justification of the present work. The current release accurately formulates the main / questions.However, a completely satisfactory solution is not yet given. According to the CPT-criteria, the expected objective to be reached by the distribution is a double one: firstly, to attend to the regional deficits due to the absolute shortages in equipment and infrastructure; and secondly, to close the gap due to the differences between the twelve regions.

In case of having information enough about both potential needs/ and actual equipments, we could find out both the relative ,and overall deficits. However, this is not the case, and we´ll be / forced to operate, in this first release, with the inter-regional relative deficits which have been subjectively estimate by the experts and political in charge of different areas in relation to equipments or infrastructure.

On the other hand, inter-regional priorities to decrease the deficits in equipments and infrastructures will be determinated by political criteria and they will be established by the CPT.

There are two main formular investing for the investment directly depending on CPT:

a) By using an economic equation which distributes the investment in a proportional way, as the European Social Fund does.

b) By using a SD-LP model to obtain the optimal distribution taking into account some linear constraints.

In both cases, a regional discomfort index is used, which is defined as

$$IZj = 0.7\ (0.8\ PAROJj + 0.2\ PAROAj) + \frac{0.30}{IRPCIj}\ ,\ j=1..12 \qquad (4)$$

Note that variations in IZj are dynamics, and they depend, among other causes, on the quantity of investment assigned to the region.

In fact, this investment contributes to decrease the unemployment and to increase the income.

The variables in (4) mean:

IZj : Regional discomfort index
PAROJj : Regional youthful unemployment
PAROAj : Regional adult unemployment
IRPCj : Regional per capita income index

Now, we´ll superficially describe both possibilities.

a) Economic equation

In this case, the criteria to distribute the investment are to

1) Assign an investment ratio to be proportional to the population size.
2) Assign an investment ratio to be proportional to the economic size, which is measured by the total employment.

3) Assign an investment ratio to be proportional to the regional geographic size.
4) Compensate the differences between the regions due to the relative deficits in equipment and infrastructure.
5) Distribute the remaining investment -once we have substracted from the total investment the first three ratios- to be proportional to the regional discomfort index.

The corresponding equations to these criteria are:

$$ICPTj = ICPT*(FPOBLA*Pj/P + FEMP*Ej/E + FSUG*SGj/SG + FEQ*Cj)$$

$$j=1..12 \qquad (5)$$

$$ICPTP = \sum_j ICPTj \qquad IIZ = \sum_j IZj$$

$$ICPTj = ICPTj + (ICPT - ICPTP)*IZj/IIZ \qquad (6)$$

The variables not described yet mean:

ICPT : Total CPT-investment
ICPTj: Regional CPT-investment
P : Total population
E : Total employment
SG : Total geographic surface size
Pj : Regional population
Ej : " employment
SGj : " geographic surface size
Cj : Equipment and infrastructure deficit index
FPOBLA:Minimum fraction of ICPT per population
FSUG : " " " " " geographic surface
FEQ : " " " " " equipment and infrastructure

Let us see now the other option

b) SD-LP model

Now a linear program is formulated where the objective function/ which we wish to maximize is the total welfare, IB,(7), defined/ as the sum of the regional welfare coefficients,(1/IZj)*ICPTj , which can be understood as the profit resulting from the investment ICPTj in the region number j, which has a discomfort (welfare) index IZj (1/IZj). Decision or activities variables are ICPTj and cost coefficients or profitabilities per invested unit value are IZj.

The interpretation is not difficult: let us assume the next single case, where T is the time

- T=k and IZ3(k) < IZ5(k)

  In this time it is more profitable to invest more in the region number three better than in number five, because number/ three is more depressed, in this period.

- T=k+1 and IZ3(k+1) > IZ5(k+1)

Now it is more profitable to invest more in the region number five because in this timestep it is more depressed.

In this way, taking into account that each timestep the system environment is different, the linear program computes the optimal distribution for each timestep of the run.

The constraints beared in mind, (8), are similar to the reported above, for the option (a). Thus, the linear program would/ be:

maximize $IB = \sum_j (1/IZj)*ICPTj$ (7)

subject to $ICPTj = ICPT$

$ICPTj \geq FPOBLA*(Pj/P)*ICPT$

$ICPTj \geq FEMP*(EMj/E)*ICPT$

$ICPTj \geq FSUG*(SGj/SG)*ICPT$

$ICPTj \geq FEQ*Cj*ICPT$

Note that the optimal solution, whether exists, should be on / the hyperplane $\sum_j ICPTj = ICPT$.

Note also that all the inequations are in the same sense (≥); to avoid redundancy we'll consider the inequation which has the highest value on the right part.

Perhaps the best way of formulating this model would be using / the SD-LP way, but the option a) is not lost of sight to cover/ the iterations where the linear program doesn't give a right solution, because either unfeasibility or unboundedness or other/ problem.

MURCIA A/I Scenarios

In order to show the possible uses of the model, various different scenarios are formulated. Suggestions are made in order to manage to the future users and specially to the CPT-technical / staff.

Firstly, the constants and tables which are more adequate to manipulate the model behaviour are suggested. These constants and tables are in relation to exogenous economic policy variables, equipment and infrastructure (to be modified when information / will be available) and CPT-investments variables.

Five different scenarios are used to run the model.

MURCIA A/I Images

An image is the set of results corresponding to the model run / with a scenario given. In order to compare the results of the / run, some tables have been included in this paper, which show / the most important consequences of the different policies to dis tribute the investment: tables 1 and 2 show the values correspon ding to both the relative per capita income indices (IRPC) and / the discomfort index (IZ) generated by the chosen scenarios. Outs tanding remarks could be:

1) IRPC´83 fluctuates between 1.126 and 0.764 with a standard deviation 0.105

2) For any image the disparities are minimized

3) The discomfort indices on 1983 fluctuate between 0.440 and / 0.310 with a standard deviation 0.041

4) Unlike it happens with IRPC, in I-4 (1986), the differences / are maximum, with limits between 0.332 and 0.457 and a stan-- dard deviation 0.0400

5) It is noted that the minimum IZ corresponding to any image on 1986 is higher than the 1983 minimum one. However, changes are not measurable.

Finally, tables 4(a) and 4(b) show the percentage distribution of CPT-investments, per region, depending on the policy (or scenario) chosen. It is obvious to note how remarkable differences exist. / Such differences involve very different impacts on both the gene-- rated remaining incomme and the generated employment. To facilita- te the comparisons the reader could see the bars diagram on appen- dix II .

		I-1	I-2	I-3	I-4	I-5
DATE		IRPC8	IRPC8	IRPC8	IRPC8	IRPC8
1986	1	.976	.969	.969	.963	.969
	2	.870	.869	.869	.872	.869
	3	.876	.865	.865	.867	.865
	4	.900	.899	.900	.901	.900
	5	.806	.802	.803	.803	.803
	6	.960	.963	.963	.969	.963
	7	.766	.753	.753	.753	.753
	8	.910	.908	.909	.909	.909
	9	1.026	1.019	1.019	1.014	1.019
	10	1.060	1.060	1.060	1.060	1.060
	11	1.116	1.106	1.106	1.105	1.106
	12	.900	.896	.896	.900	.900

DATE		IRPC83
1983	1	.976
	2	.860
	3	.855
	4	.890
	5	.806
	6	.940
	7	.746
	8	.900
	9	1.036
	10	1.060
	11	1.126
	12	.900

Table 1 Regional per capita income

	IRPC83
COUNT	12
MINIMUM	.746
MAXIMUM	1.126
MEAN	.9245
VAR	.0109
STD DEV	.1047

RANGE: 1983 1 TO 1983 12

	IRPC86I1	IRPC86I2	IRPC86I3
COUNT	12	12	12
MINIMUM	.766	.753	.753
MAXIMUM	1.116	1.106	1.106
MEAN	.9305	.92575	.926
VAR	>>>>>>>>>	>>>>>>>>>	>>>>>>>>>
STD DEV	.09777226	.09850983	.09836835

RANGE: 1986 1 TO 1986 12

	IRPC86I4	IRPC86I5
COUNT	12	12
MINIMUM	.753	.753
MAXIMUM	1.105	1.106
MEAN	.92633333	.92633333
VAR	>>>>>>>>>	>>>>>>>>>
STD DEV	.09746908	.09827286

RANGE: 1986 1 TO 1986 12

Table 2 Statistical analysis of the per capita income

DATE		IZ83	DATE		I-1 IZ86I	I-2 IZ86I	I-3 IZ86I	I-4 IZ86I	I-5 IZ86I
1983	1	.350	1986	1	.370	.373	.374	.382	.374
	2	.415		2	.424	.419	.419	.424	.419
	3	.380		3	.380	.381	.381	.383	.381
	4	.435		4	.455	.450	.450	.457	.450
	5	.420		5	.430	.432	.432	.437	.432
	6	.365		6	.365	.362	.362	.363	.362
	7	.440		7	.440	.445	.445	.448	.445
	8	.365		8	.375	.374	.374	.378	.374
	9	.320		9	.330	.328	.328	.332	.328
	10	.345		10	.365	.364	.364	.370	.365
	11	.310		11	.330	.330	.330	.334	.330
	12	.365		12	.385	.375	.375	.378	.375

Table 3(a) Regional discomfort indices

	IZ83
COUNT	12
MINIMUM	.31
MAXIMUM	.44
MEAN	.3758
VAR	>>>>>
STD DEV	.0413

RANGE: 1983 1 TO 1983 12

	IZ8611	IZ8612	IZ8613
COUNT	12	12	12
MINIMUM	.33	.328	.328
MAXIMUM	.455	.45	.45
MEAN	.38741666	.38608333	.38616666
VAR	>>>>>>>>>	>>>>>>>>>	>>>>>>>>>
STD DEV	.03937100	.03958210	.03955551

RANGE: 1986 1 TO 1986 12

	IZ8614	IZ8615
COUNT	12	12
MINIMUM	.332	.328
MAXIMUM	.457	.45
MEAN	.3905	.38625
VAR	>>>>>>>>>	>>>>>>>>>
STD DEV	.04004684	.03950975

RANGE: 1986 1 TO 1986 12

Table 3(b) Statistical analysis of the discomfort indices

		I-1	I-2	I-3	I-4	I-5
DATE		ICPT%	ICPT%	ICPT%	ICPT%	ICPT%
1983	1	7.83	6.82	6.87	4.74	7.42
	2	9.18	9.19	9.29	6.38	9.79
	3	8.41	4.11	4.10	2.27	4.71
	4	9.53	9.86	9.94	9.51	10.46
	5	9.35	6.00	5.96	4.88	6.57
	6	8.02	5.69	5.66	4.93	6.29
	7	9.87	3.67	3.61	1.33	4.27
	8	8.10	3.96	3.91	1.83	4.56
	9	7.08	6.26	6.22	6.35	6.86
	10	7.65	23.16	23.17	34.19	18.96
	11	6.91	15.81	15.82	19.68	14.01
	12	8.08	5.50	5.46	3.92	6.10

		I-1	I-2	I-3	I-4	I-5
DATE		ICPT%	ICPT%	ICPT%	ICPT%	ICPT%
1986	1	8.07	6.87	6.92	4.77	7.47
	2	9.04	9.14	9.25	6.32	9.74
	3	8.21	4.06	4.04	2.23	4.66
	4	9.72	9.91	9.98	9.51	10.51
	5	9.31	5.95	5.95	4.87	6.55
	6	7.82	5.63	5.60	4.83	6.23
	7	9.58	3.60	3.54	1.33	6.20
	8	8.06	3.95	3.89	1.83	4.55
	9	7.09	6.26	6.22	6.39	6.86
	10	7.87	23.26	23.26	34.25	19.06
	11	7.13	15.88	15.88	19.75	14.08
	12	8.10	5.50	5.45	3.91	6.10

Table 4(a) CPT- investment distribution

	I-1	I-2	I-3
	ICPT% ICPT%	ICPT% ICPT%	ICPT%
COUNT	12	12	12
MINIMUM	6.91	3.67	3.61
MAXIMUM	9.87	23.16	23.17
MEAN	8.334	8.335	8.334
VAR	.8402	30.37	30.59
STD DEV	.9166	5.511	5.531

RANGE: 1983 1 TO 1983 12

	I-4	I-5
	ICPT%8314	ICPT%8315
COUNT	12	12
MINIMUM	1.33	4.27
MAXIMUM	34.19	18.96
MEAN	8.3341666	8.3333333
VAR	82.537457	17.579138
STD DEV	9.0850128	4.1927483

RANGE: 1983 1 TO 1983 12

	I-1	I-2	I-3
	ICPT%8611	ICPT%8612	ICPT%8613
COUNT	12	12	12
MINIMUM	7.09	3.6	3.54
MAXIMUM	9.72	23.26	23.26
MEAN	8.3333333	8.3341666	8.3316666
VAR	.71800549	30.852474	31.032497
STD DEV	.84735204	5.5545003	5.5706819

RANGE: 1986 1 TO 1986 12

	I-4	I-5
	ICPT%8614	ICPT%8615
COUNT	12	12
MINIMUM	1.33	4.55
MAXIMUM	34.25	19.06
MEAN	8.3325	8.5008333
VAR	83.029202	16.860974
STD DEV	9.1120361	4.1062116

RANGE: 1986 1 TO 1986 12

Table 4(b) Statistical analysis of investment distribution

CONCLUSIONS

As we said above, this work is about a first release of the model for the investments planning. To improve the current release it will be necessary to dispose more statistic data about the actual community of Murcia state. Moreover, some ideas and suggestions could be useful to

a) Establish an average productivity of the regional employment with actual regional income data

b) Introduce an economic distance index associated with the distribution percentage of the constant FDE (minimum fraction of ICPT due to economic distance) whose current value is 0

c) Use welfare indices associated with known equipments (telephones, roads, hospital beds, sewer system, schools, etc.)

d) Recalibrate the model when 1983 information from Bilbao Bank for our region will be available

REFERENCES

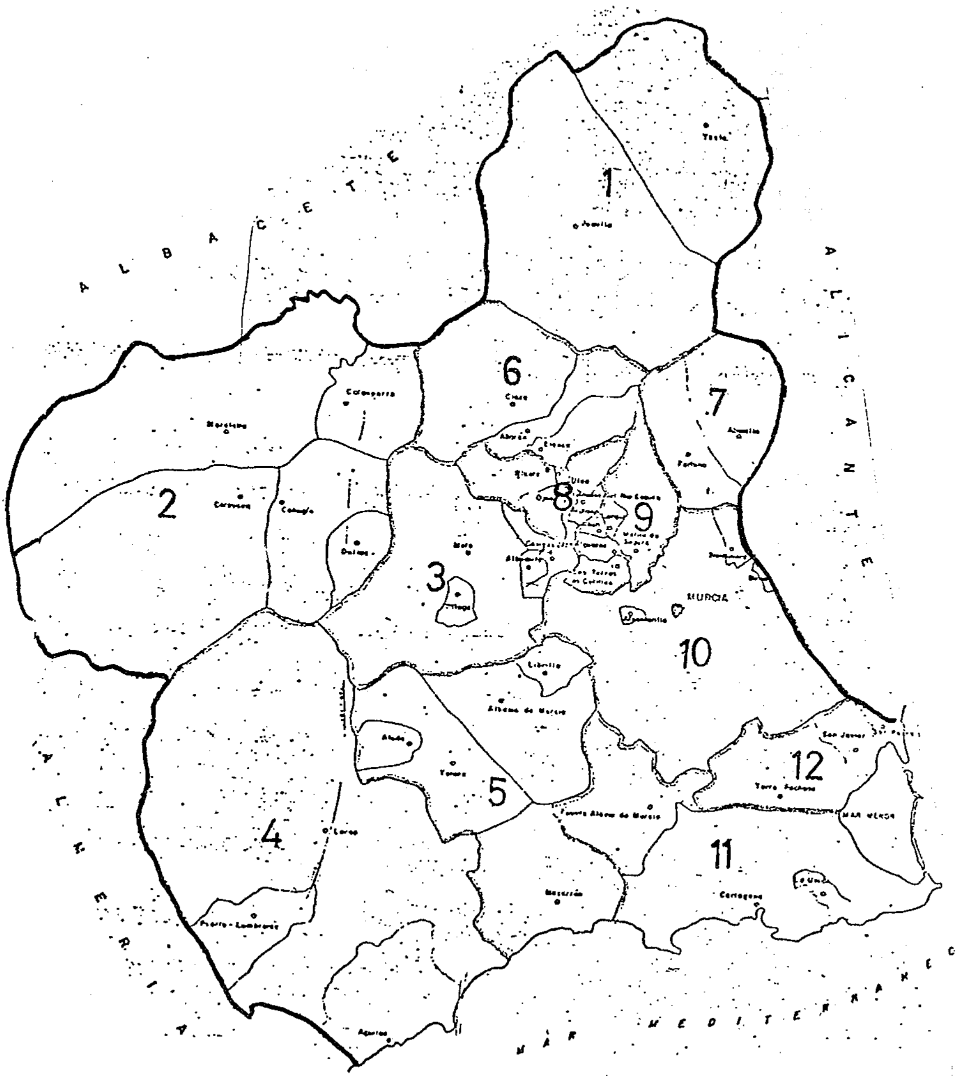
Martínez, S.(1983) Murcia 2000/II/. Pensando en el futuro. Un modelo de dinámica de sistemas para la Región de Murcia.

Prawda, J. (1982) Métodos y modelos de Investigación de Operaciones. Ed.Limusa

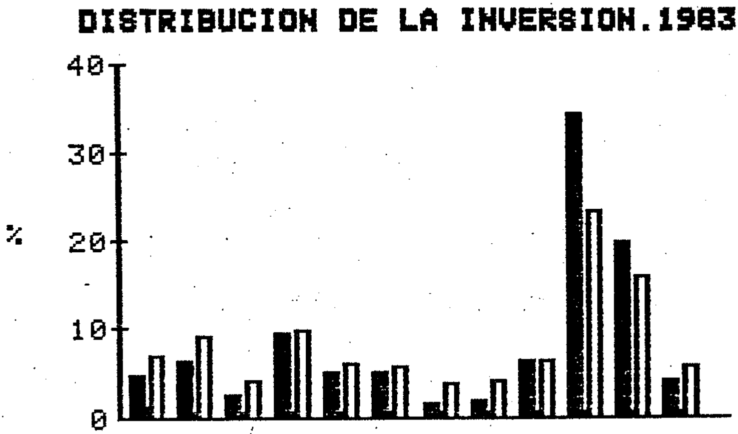
Sakarovitch(1983) Linear Programming. Springer Verlag

Toval, A. (1985) Uso de técnicas de programación lineal en dinámica de sistemas. Actas del VI Congreso de Informática y Automática. Servicio de Publicaciones E.T.S.I. de Telecomunicacion Cdad. Universitaria, s/n.(28040) Madrid

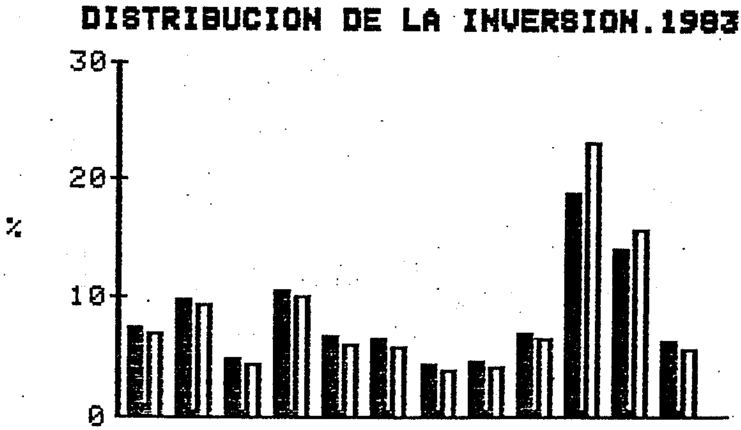
APPENDIX I. GEOGRAPHIC SITUATION



APPENDIX II. BARS DIAGRAMS

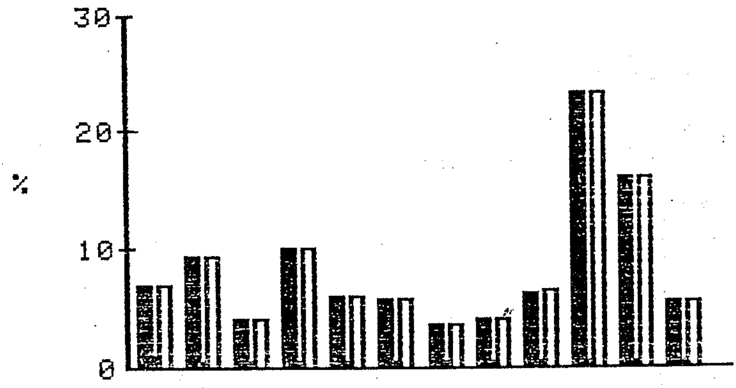


IZQUIERDA "IMAGEN-4"
DERECHA "IMAGEN-2"



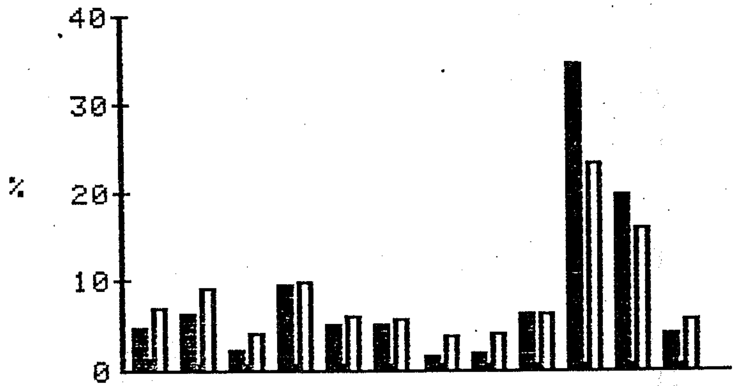
IZQUIERDA "IMAGEN-5"
DERECHA "IMAGEN-2"

DISTRIBUCION DE LA INVERSION.1986

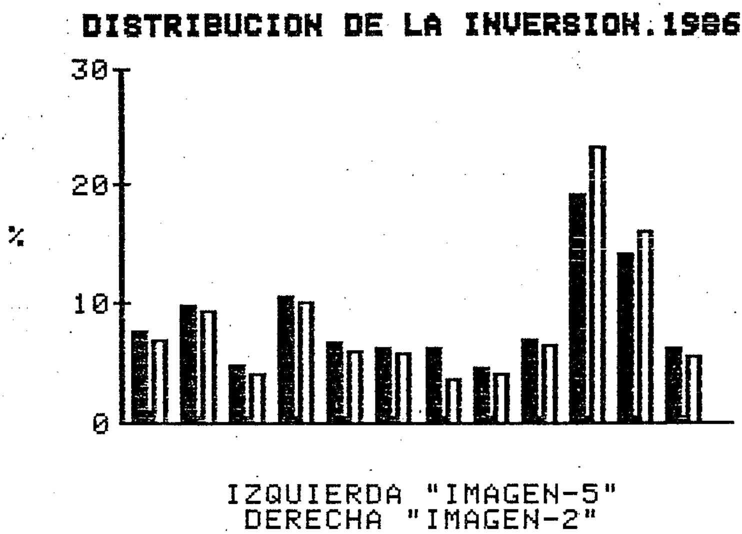


IZQUIERDA "IMAGEN-3"
DERECHA "IMAGEN-2"

DISTRIBUCION DE LA INVERSION.1986



IZQUIERDA "IMAGEN-4"
DERECHA "IMAGEN-2"


DISTRIBUCION DE LA INVERSION.1986
30
20
%
10
0
IZQUIERDA "IMAGEN-5"
DERECHA "IMAGEN-2"

APPENDIX III. FORRESTER DIAGRAM (A/I)