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MODELLING THE SOCIO-ECONOMIC DEVELOPMENT OF A NEW AGRICULTURAL REGION

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In this paper are presented:
The main problems appearing in the organization, planning and management of Research Programs in the particular conditions of a developing country, Cuba.
Some mathematical models applied to the socio-economical-development of a new agricultural region.
Algorithms and programs to collect and to process information coming from experts. These algorithms are applied - to the microlocalization of socio-economical objects.

INTRODUCTION

The developing countries face great problems in the efficient exploitation of their resources. In order to solve the top-priority problems related- to social and economic development, i is necesary to concentrate to the- maximum the efforts of all the organizations, mainly those of research -- institutions. The solving of each one of these problems requires the - implementation of complex, long-range research programs, with well-defi-- ned aims and the participation of several research and production organizations. Programs concerning the development of new economic regions and mainly those related to agroindustrial regions are extremely necessary, - but only seldom carried out in developing countries.

The main objective of the research program is to develop the policy for - the long range socio-economical development of a region, and mainly to:

- establish the correct rythm and proportions for the development of the region;
- reach the stability in the development and management of natural, hu-- man and material resources;
- develop the social infraestructure allowing to stabilize the quantity- structure, settlement and reproduction of labor forces,
- to maximize the net integral effect (profit) of the economical activities in the region;

A retrospective analysis of the economic development of the region was performed, in order to have a clear picture of its current situation and trends

The main results of the analysis were:

- the need of increasing the efficiency of the organization and planning of the program, due to its complexity and to the lack of experience in our country;
- the need of using formal methods to process the qualitative information reported by the experts, due to the lack of reliable statistical data;
- the need of developing some mathematical models for planning long range agricultural production;
- to characterize the social factors affecting the economic development of the region.

Some of the experiences achieved in the organization and planning of a Research Program are offered, as well as, some implemented mathematical models, and the approach used to microlocalize the socio-economic objects in a new agroindustrial region.

MAIN FACTORS OF THE PROGRAM

When we analize the Reseach Program (DIPOTET-79), we observe there are, in -- our country, external factors, that we must take as compulsory, and internal-factors, particular for the Region, determining, to some extent, its development.

The external factor "policy for long range socio-economical development of -- the country" determine:

- global requirements in products, raw materials and services from the Re--- gion;
- the external resources to be allocated in the Region;
- indicators for social and institutional infraestructure to be developed in the Region.

In short, the economic development of the Region mainly depends on the effi- - cient management and exploitation of the external resources in the sense of - satisfying the requirements. Thus, it is possible to distinguish the follo-- wing strongly related general aspects:

- To develop and stabilize the population of the Region. Therefore, it is - needed to derive demographic models, to characterize the social factors -- affecting the economic development and to control the migration.
- To characterize the natural resources of the Region. Therefore, it is ----- needed to do a very complex work, the inventory and evaluation of these -- resources.
- To know and to evaluate the material resources, the available infraestructure and the tradition and experiences of the inhabitants of the Region.-- Therefore, it is needed to perform a retrospective analysis of the socio-- economic development of the Region, in order to derivea diagnosis of its - present situation.
- Conservation and, if possible, amelioration of the environment, mainly taking care of the consequences of human economical activities on natural re sources, Therefore, it is needed to estimate local and global limits in - the exploitation of these resources.
- The organization and management of the former four factors in order to --- maximize the net effect (global profit) of the socio-economical activities of the Region.

Each one of the former points may be considered, due to its compexity, as a-research subprogram where several organizations must participate in.

Being a developing region, it was needed to apply a dynamic approach in the works of the Program (Fig. 1). This approach allowed us to improve, frequently, the available information about the object, and to use the new information in decision making.

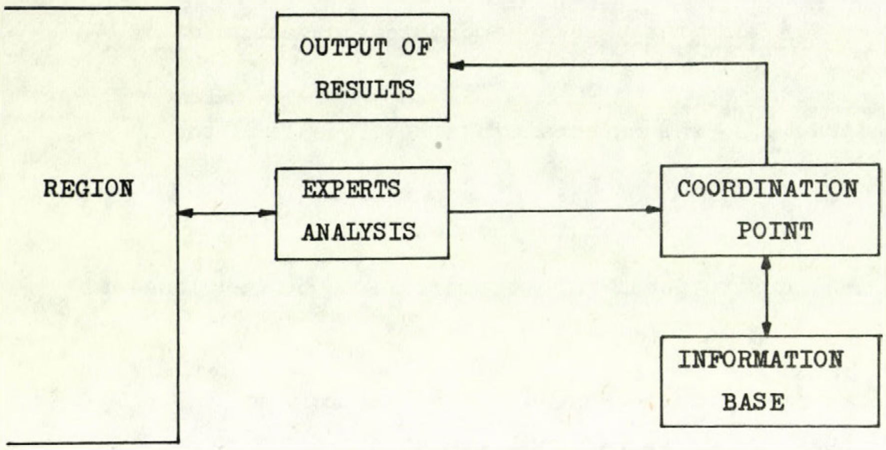


Fig. 1 Preliminary system to study the Region

With the improvement of the information base and, therefore, the new knowledge about the object and its environment it is possible to develop an information-system for planning long range economic development of the Region (DIPOTET-79) In other words, it is needed to perform the planning of long range investments projects for the Region based on some kind of man-machine system helping the -

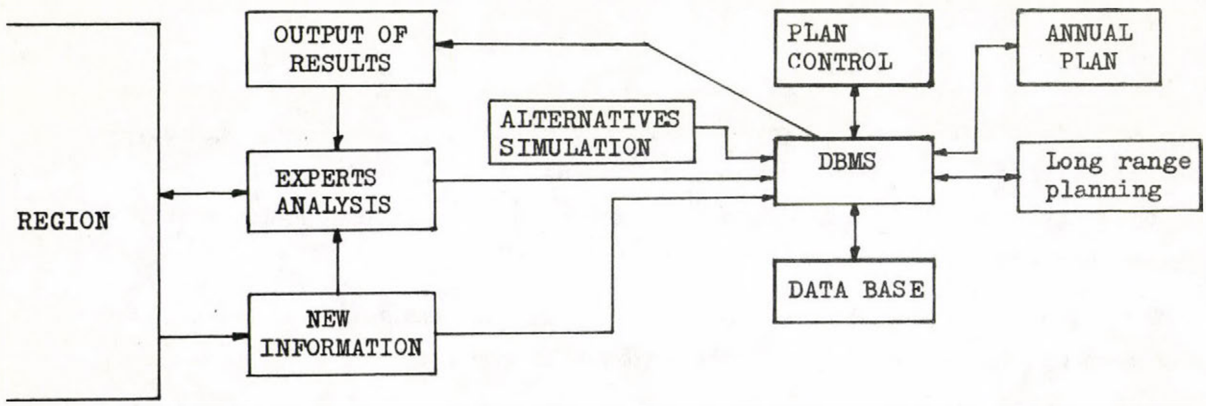


Fig. 2 System for planning long range economic development of the developing Region

"man", responsible for decision making, to evaluate the consequences of different plan alternations and to control, if necessary, the deviations of actual-plans.

Some mathematical tasks to be solved within the Research Program are:

1- To derive formal methods for the management of Research Programs in our - particular conditions.

2- To develop models for rational land exploitation.

3- To develop models for planning long range agricultural production.

4- To derive models for the microlocalization of socio-economical objects.

5- To develop models and MIS for the main enterprises of the Region.

Next we present some results about the Programs management, and the first version of the mathematical models implemented in the developing Region.

ORGANIZATION AND PLANNING OF THE PROGRAM

Production and service enterprises deal with concrete and well-defined tasks and subtasks. Scientific institutions deal with research themes. Thus, ---- themes must be formulated for each institution from the activities and jobs - belonging to the tasks of the program assigned to them.

Next we will present the procedures that must be carried out for collecting - and processing the data that will enable us to derive the reseach plan.

Let a set $J = (1, \ldots, n)$ of research institutions belonging to one organization which must carry out a research program P in a given time T.

The Scientific Council of the Organization divides the Program P into several sets of important tasks $P_1, P_2, \ldots, P_m$.

Then, $P = (P_1, \ldots, P_m)$.

We use the form given in Fig. 1 to obtain the listing of the institutions of-the organization vs the tasks that they are going to undertake, respectively. For each $P_i \in P$; $i \in I = (1, \ldots, m)$ the Scientific Council establishes the deadline time $t_i \leq T$.

This deadline time t_i depends on several factors, but mainly on the will of - the user and the domestic requirement of the Organization.

The performance of each task is divided into r subtasks, for example in the-following 12 subtasks:

1) description of the tasks
2) formalization of the task
3) selection of methods and techniques to solve the task
4) collection and filtering of data
5) development of algorithms
6) programming
7) implementation of programs
8) analysis of results
9) improvement of the description of the task
10) modelling improvement
11) implementation of the solution of the task
12) drafting of reports, handbooks and user instructions.

The form shown in Fig. 2 offers the listing of all institutions vs the ---- subtasks where they will participate, respecively.

Tasks	INSTITUTES									ENTERPRISES						
	ACC	Bot.	Geog.	IMACC	Met.	Ocea.	Suel.	Zool.	P.P.	MINAG	CEATM	CONST.	Mat. Const.	Hid. Econ.	Educ.	Transp.
1		+	+	+	+					+						
2				+						+	+	+	+	+	+	+
.																
.																
10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Fig. 1 Institutions vs Tasks

Subtasks / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	Name of participants
1													
2													
.													
.													
10													

Fig. 2 Institutions vs subtasks

The Research Council builds up, using these forms (see Fig. 2)

the matrix $A^j = \left\| a^j_{il} \right\|_{mxr}$ where $a^j_{il} \in (0,1)$; $i \in I = (1, \ldots, m)$

$j \in J = (1, \ldots, n)$

$l \in L = (1, \ldots, r)$

$a^j_{il} = 1$ means that institute j participates in the carrying out of task i in- the subtask l. The institution j lists the jobs and activities to be perfor- med within the time interval t_i, for each case $a^j_{il} = 1$. The research themes- are elaborated with the former list and the unification and generalization of other activities. The resources needed are established as well as the onset - and completion dates.

In those cases when $\sum a^j_{il} = 0$; $j \in J$; $i \in I$; $l \in L$; in other words, when none of the n institutions participate in the solution of one subtask a_{il}, it is - necessary to find other institutions that would open new themes concerning -- subtask a_{il}.

The form shown in Fig. 3 in used to list the research themes of the Program - vs the subtask where they will take part, respectively. These three forms -- are the additional blanks that must be filled out in the organization and --- planning (ACC-80) of the Program.

Program P is then formed by a set W = (1, ..., s) of research themes.

Let $a^w_{il} \in (0,1)$ denote each element (subtask a_{il} related to theme w) in Fig.3 $w \in W$; $i \in I$; $l \in L$ each theme w, $w \in W$ is then related to a set A^w of sub---- tasks a^w_{il}.

Then, $A^k \cap A^0 = A^{k0}$; k, $0 \in W$; is the set of subtasks where both themes k, 0- participate in simultaneously, cardinal N_{k0} of set A^{k0} is considered to indi- cate some relationship between themes k and 0; k, $0 \in W$.

The graph shown in Fig. 4 is the matrix $N = \left\| N_{k0} \right\|_{sxs}$ formed by cardinals- of the intersections sets (see Fig. 4) will, of course, be symmetric in res-- pect to the main diagonal.

In our case, we separate from the graph a subgraph, the maximun linked tree.- Each node of the tree will be a theme. The value of the links will be given- by their correspondent elements in matrix N, indicating some degree of rela- tionship among the themes.

The procedure to construct the tree is the following:

1) Selection of the maximum element N_{pp} in the main diagonal of matrix N. Node (theme) p is the root of the tree hierarchical structure -

Tasks Themes	1	2	3	4	5	6	7	8	9	10
10180230 (1,1)	1,4, 8 9,12		1,4,8 9, 12	1,4,8 9,12	1,4,8 9,12	1,4,8 9,3		1,4,8 9,3	1,4,8 9,3	4,11
10280222 (1,2)	1,2,4, 8,9,12		1,2,4, 8,9,12		1,2,4, 8,9,12	1,2,4, 8,9,12		1,2,4, 8,9,12	1,2,4, 8,9,12	4,11
10380143 (1,3)	1,4,5, 8,9,12	1,4,5, 8,9,12	1,4,5, 8,9,12						1,4,5, 8,9,12	4,11
10480535 (1,4)	1,2,3, 4,9,12		1,2,3, 4,9,12					1,2,3, 4,9,12	1,2,3 4,9,12	4,11
10580541 (1,5)	1,4						1,2, 4,7, 8,9, 10,12		1,4	4,11
10780521 (1,6)	1,2,4, 8,9,12		1,2,4, 8,9,12		1,2,4, 8,9,12				1,2,4, 3,8,9, 12	4,11
10781521 (1,7)	1,2,4, 8,9,12		1,2,4, 8,9,12						1,2,3, 4,8,9	4,11
10980222 (1,8)	1,2,4, 8,9,12		1,2,4, 8,9,12		1,2,4, 8,9,12			1,2,4, 8,9,12	1,2,4, 8,9,12	4,11

Fig. 3 Themes vs subtasks

Themes / Themes	1	2	3	4	5	. . . .	25	26	27	28	29	30
1	37											
2	32	38										
3	17	17	26									
4	18	18	14	26								
5	6	6	6	6	14							
.		.			.							
.		.			.							
.		.			.							
.		.			.							
.		.			.							
.		.			.							
.		.			.							
25	17	17	26	14	6	. . . .	26					
26	7	10	8	14	2		8	35				
27	30	32	22	22	11		22	35	100			
28	2	2	2	2	2	. . . .	2	5	6	11		
29	2	2	2	2	2		2	2	2	3	12	
30	2	2	2	2	2		2	2	2	5	3	6

Fig. 4

of the tree.

2) If tree has not free nodes then go to 3 else, search the nodes[1] corresponding to the next level testing the following conditions;

   2.1) Inf $N_{pi} \geq N_{ki}$ for each k; k, i, p $\in$ W; p $\neq$ i $\neq$ k $\neq$ p; then node-i is linked to node p in the former level and is a leaf of the -- tree.

   2.2) If $N_{pk} \geq N_{pi} \leq N_{ki}$ for each k; k, i, p $\in$ W; i $\neq$ p $\neq$ k $\neq$ i;- then node p is linked to node i in the former level.

   2.3) If $N_{pk} > N_{pi} < N_{ki}$ for, at least, one k; k, i, p $\in$ W; ----- i $\neq$ p $\neq$ k $\neq$ i; then node i is not linked to node p. If there is- another node in former level, then DO p that node and go to 2.1,- else ADD 1 to the level counter and GO TO 2.

3) EXIT.

   In Fig. 5 the maximun linked tree is shown.

   In our example, this subgraph aids the leaders of the program in decision-making concerning the management of the research.

   For example:

   a) it is obvious that theme 27 is really a "bottleneck", and it is -- absolutely necessary to assure its resource allocation;
   b) the subtrees derived from nodes 2 and 3 respectively may be considered as subprograms to improve program management;
   c) themes 4, 12, 5, 17, 26 are practically isolated and it may be --- possible that their works may begin in advance or be delayed ----- (within time interval t_i), according to resource allocation pro--- blems.

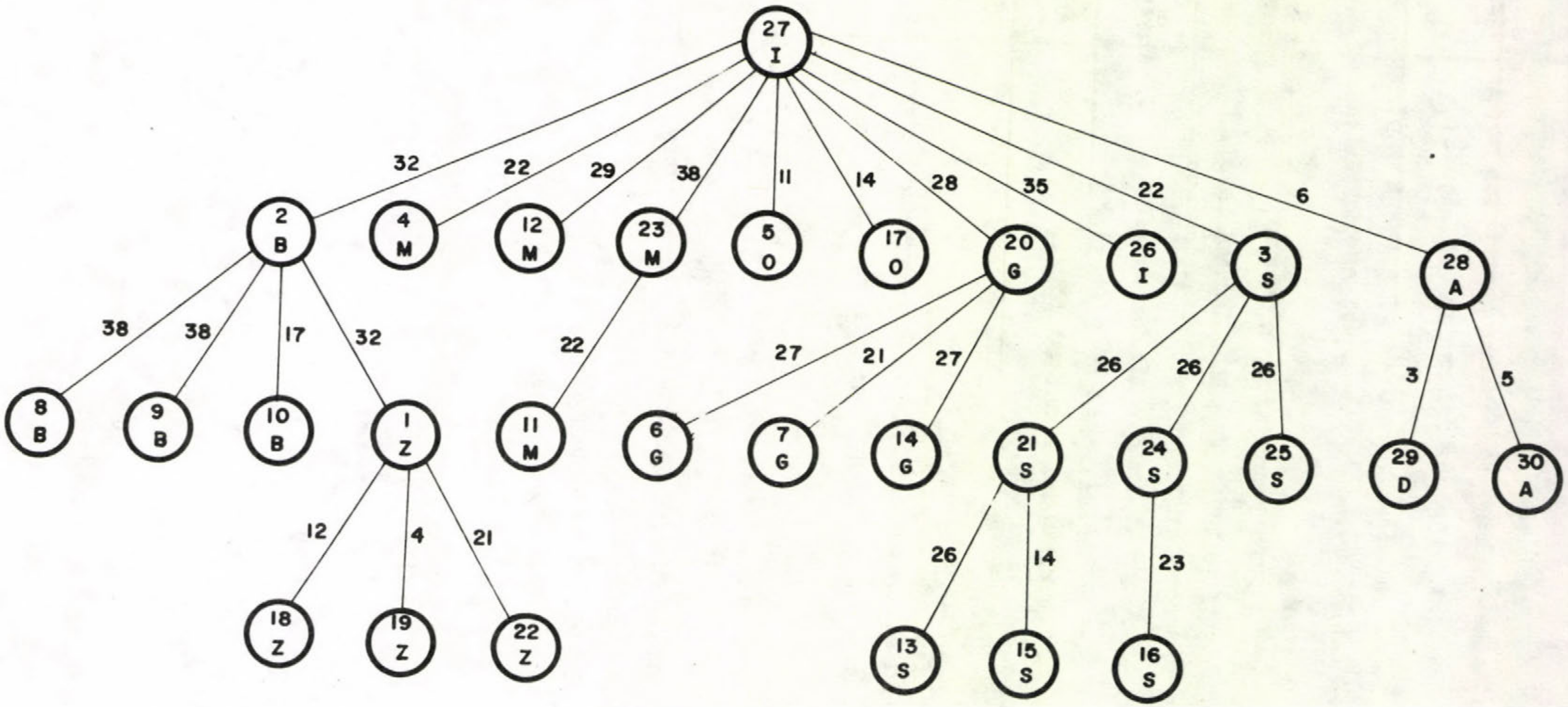
What we have presented above are only examples. There are many applications- of the tree and it is also possible (Dipotet, 1980) to derive other useful -- subgraphs from the graph shown in Fig. 5.

RESOURCE ALLOCATION PROBLEMS

With the information received from the themes of the Program for each task -- P_i, $P_i \in P$; $i \in I$; we establish its working stages ($P_i(1)$, ..., $P_i(t_i)$), ---- where $P_i(t)$, $i \in I$; $t \leq t_i$; is the working stage in time t.

For each $P_i(t)$ we determine its resource vector

1 See the detailed algorithm in (Dipotet-80)



MAXIMUM LINKED TREE

Fig. 5

$r_i(t) = (r_{i1}(t), \ldots, r_{ik}(t), \ldots, r_{iq}(t))$

where $k \in K = (1, \ldots, q)$ is the resource number.

Then $\sum_{i \in I} r_{ik}(t) = R_k(t)$, resource requirements <u>k</u> in time <u>t</u>.

The function $R_k(t)$ may vary (see Fig. 6). In some cases, the resource k, --- $k \in K$, is difficult to obtain, but generally the "rate of change" of the re-- source -maximum or minimum increase or decrease at the time unit- is known.

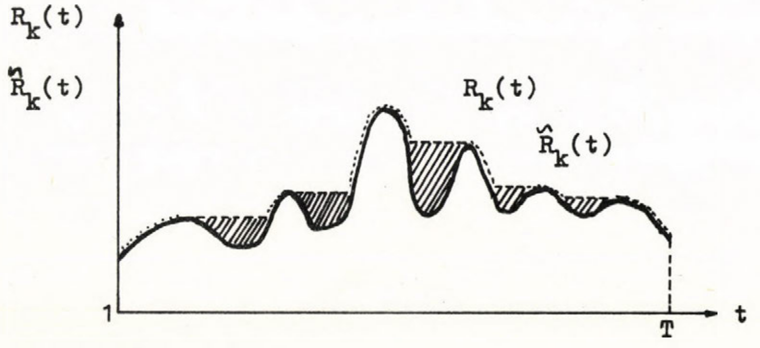


Fig. 6

In these cases, it is convenient to use function, (see Fig. 6) with only one maximum and $\max_t R_k(t) = \max_t \hat{R}_k(t)$.

However, when we have some surplus in a given resource, <u>k</u> for example, (see - Fig. 6), this surplus may be used in other research programs during the same- time interval <u>T</u>. When it is not possible to use them, it seems reasonable to reduce them so that $\max_t R_k(t)$ could be the minimun amount, and $R_k(t)$ will be almost parallel (Fig. 7) to axis <u>t</u>.

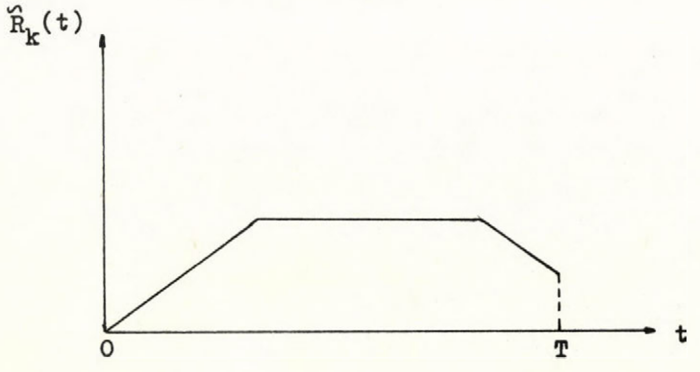


Fig. 7

We tried to solve the former problem as follows:

a) varying the content of stages $P_i(t)$ and, therefore, vector $r_i(t)$, -- but maintaining value t_i;

b) varying the set of tasks P_i, or participating in another set of ---- tasks;

c) varying $t_i \leq T$, but keeping the stage contents;

d) combining the former three approaches.

Next we describe one algorithm for building up the function $R_k(t)$. Suppose - we know the maximun rate of increasing (V_k) and decreasing (D_k) resource k. We find $R_k = \sum R_k(t)$ and $h_k = \frac{R_k}{T}$; if $h_k \leq V_k$ and D_k, then $\hat{R}_k(T) = h_k$; if $D_k > h_k > V_k$, then $\hat{R}_k(1) = V_k$ and $h_k^1 = \frac{R_k - V_k}{T - 1}$.

We then compare h_k^1 with 2 V_k and D_k.

If $h_k^1 \geq 2V_k$ then $\hat{R}_k(2) = 2V_k$;

If $h_k^1 > D_k$ then $\hat{R}_k(T) = D_k$.

Then, form $R_k - V_k$ we substract, respectively, $2V_k$ or D_k (or both) and divide by T - 2 or T - 3 to obtain h_k^2 .

The Procedure continues, until step r where $l_2 D_k \leq h_k^r \geq l_1 V_k$; $l_1, l_2 \in Z = (1, 2, \ldots, z)$. Thus in the former (r-1) steps the values of fuction $\hat{R}_k(t)$ for $0 \leq t \leq l_1 - 1$ and $T - C_2 + 2 \leq t \leq T + 1$ ($\hat{R}_k(0) = \hat{R}_k(T+1) = 0$) were obtained.

For other t values, $l_1 \leq t \leq T - l_2 + 1$, we suppose $\hat{R}_k(t) = h_k^r$.

Thus, $\hat{R}_k(t)$ is derived for all t, $t \in (1, \ldots, T)$.

From the algorithm it follws that $\sum_{t=1}^{T} \hat{R}_k(t) = \sum_{t=1}^{T} R_k(t)$.

However, it may be possible not to satisfy the resource constraints. It means $\sum_{i \in I} r_{ik}(t) \neq \hat{R}_k(t)$.

It is possible to determine which resource distribution satisfies the cons--- traints for all tasks and all times <u>t</u> for $\hat{R}_k(t)$ function.

We determine coefficient $a_k(t) = \frac{\hat{R}_k(t)}{R_k(t)}$ and derive for each task i, $i \in I$, -- the resources vectors $r_i^1(t)$, $r_i^1(t) = (r_{i1}(t).a_1(t), \ldots, r_{iq}(t).a_q(t))$.

For it, $\sum_{i \in I} r_{ik}(t).a_k(t) = a_k(t) \sum_{i \in I} r_{ik}(t) = a_k(t).R_k(t) = \hat{R}_k(t)$.

In this case, we assign $r_i^1(t)$ to each stage $P_i(t)$, $i \in I$; $t \in (1, \ldots, T)$; --- instead of $r_i(t)$, then the works must be updated within the stage.

It may happen that, for some tasks, resources are not enough for the whole -- time interval T and for other task they are in exceses. Then, experts must - analize and rectify the resource distribution plan. However it is possible - to apply mathematical programming methods for estimating the optimal, in a --

certain sense, resource distribution plan.

For example, the following quadratic programming problem is cosidered. To - determine X(t) values satisfying

$$\min \sum_{t=1}^{q} \sum_{k=1}^{q} \left[R_k(t).X(t) - \hat{R}_k(t)\right]^2$$, with the constraints

$$\sum_{t=1}^{T} r_{2k}(t).X(t) = \sum_{t=1}^{T} r_{ik}(t);\ X(t) \geq);\ i \in I.$$

In this work we have T variables and q x m type equality constraints.

Suppose we obtain the solution for X9TO = 1 for all t = (1, ..., T) using it as initial solution, it is possible to continue using, e.g., the gradient -- method.

This problem statement is not at all senseless. It means that the resource allocation of each stage of all tasks with the same proportionality coeffi-- cient must be changed, in order to obtain a resource distribution plan, for- time interval T, as near as possible to be best $R_k(t)$ (Fig. 7) and assurring for every task that the total requirement in T for every resource is obtai- ned.

PARCELS DISTRIBUTION IN REGIONAL PLANNING

For the solution of this task we used different linear programming models. - Let us present (DIPOTET-81) the simplest one.

Let:

J = $(1, \ldots, n)$ be the set of towns (or users of the agricultural production);

K = $(1, \ldots, k)$ be the set of differents productions;

I = $(1. \ldots, m)$ be the set of parcels;

S_i = the area of parcel i, $i \in I$;

r_i^k = the production per unity of area of type k, $k \in K$, culture in parcel i;

d_i^k = costs associated to the production of k, $k \in K$, in parcel i, $i \in I$;

b_j^k = transportation cost for the unity of k, $k \in K$, form parcel i, $i \in I$, to consumer j, $j \in J$;

e_j^k = costs related to the consumption of the k product by the consumer j, $j \subset J$;

The task is how to distribute the parcels in order to satisfy the demands with - minimum costs.

Let us denote by x_{ij}^k the volumes of type k product transported form parcel i, -- $i \in I$, to consumer j, $j \in J$. Then, our task is to solve the following linear programming problem:

to determine: $$\min_{x_{ij}} \quad {}_{i \in I} \quad {}_{j \in J} \quad {}_{k \in K} \; (c_{ij}^k + d_i^k + e_j)\, x_{ij}^k$$

with the constraints:

$$_{j \in J} \quad _{k \in K} \; \frac{x_{ij}^k}{r_i^k} = S_i$$

$$_{i \in I} \; x_{ij}^k = b_j^k$$

$$x_{ij}^k = 0$$

Let us suppose the solution for this task is

$$x_{ij}^k = \underline{x}_{ij}^k$$

Then we obtain

$$\underline{x}_i^k = \sum_j \underline{x}_{ij}^k$$

The volumes of k products in parcel i, i I, and

$$\underline{s}_i^k = \frac{\underline{x}_{ij}^k}{r_i^k}$$

the areas of parcel i, i$\in$ I, planted with k, k K.

This simple model may be complicated (DIPOTET-81) with other constraints related to resources, production technology, manpower and also the dynamic of - the Region. Then, it may be possible to use a block type linear programming problem (GOLSHTEIN-66).

In our case (the development of a new Region) it is needed to find mechanisms to intensify the production and to improve efficiency enterprises using this-resource (land).

For this reason we added to the former model the following elements:

= (1,2, ..., T) a set of time periods; is the planning period;

p_k^t = price (estimated) for product k, k K at time period t, t .;

f_i^t = cost associated to parcel i, i$\in$ I, at time t, in order to be considered suitable for planting;

l_i^t = cost (tax) for 1 ha of parcel i, i$\in$ I, at time period t ;

PLANNING PERENNIAL CROPS

For the solution of this task, it is possible to use different models ------- (DIPOTET-81). We think, in our particular, case, the most suitable approach- is the simulation optimization one (BEAUSOLEIL-80) but it presents some imple mentation problems. For this reason we have developed and implemented, with- good results, a linear programming model (ALEXEIEV-DIPOTET-1978), similar, in some sense, to Csaki's ideas (CSAKI-76). Next we present these ideas and afterwards our model.

Let

$J = (1, \dots, j)$ be the set of hectareas in a given region;

$\mathcal{T} = (1, \dots, T)$ be the set of time periods, T is the planning horizon;

$x_j(t)$ = the number of hectareas used for perennial crop j, $j \in J$, at period t, $t \in \mathcal{T}$;

$k_j^+(t)$ = the number of hectareas, used for new plantings of perennials of type j, $j \in J$, at time t, $t \in \mathcal{T}$;

$k_j^-(t)$ = the number of hectareas of perennial of type j removed at year t, --- $t \in \mathcal{T}$;

b_{jk} = proportion of lands of type k, $k \in J$, (i.e. with trees of type k) progressing to type j, $j \in J$, in one year.

The state equations are then defined as

$$x_j(t+1) = \sum_{k=1}^{s} b_{jk}(t)\, x_k(t) + k_j^+(t) - k_j^-(t)$$

or in matrix form

$$x(t+1) = Bx(t) + k^+(t) - k^-(t)$$

where $x(t) = (x_1(t), \dots, x_s(t))$ is the set state vector

and $k^+(t) = (k^+_1(t), \dots, k_s^+(t))$; $k^-(t) = (k_1^-, \dots, k_s^-(t))$ are the control vectors.

We ilustrate the state equations por the perennial crop with an example of citrus fruit production. Consider de following production time periods:

	Age of trees Years
$x_1(t)$	0 - 1
$x_2(t)$	1 - 2
$x_3(t)$	2 - 3

$x_4(t)$ 3 - 4

$x_5(t)$ 4 . . . producing * or mature tress

The state equation for new plantings is

$$x_1(t+1) = k_1^+(t)$$

the trees in the second year

$$x_2(t+1) = b_{21}x_1(t)$$

$$\begin{array}{cc} \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \end{array}$$

and trees in the fith and succeding years (producing or mature trees)

$$x_5(t+1) = b_{55}x_5(t) + b_{54}x_4(t)$$

With the given $b_{jk}(j = 1, \ldots, 5)$ $(k = 1, \ldots, 5)$

In the matrix form the state equations are written:

$$x(t+1) = Bx(t) + hk_1^+(t);$$

where

$$B = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ b_{21} & 0 & 0 & 0 & 0 \\ 0 & b_{32} & 0 & 0 & 0 \\ 0 & 0 & b_{43} & 0 & 0 \\ 0 & 0 & 0 & b_{54} & b_{55} \end{bmatrix} \qquad h = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

here we have 5 state variables $x(t) = (x_1(t), \ldots, x_5(t))$; one control variable $k_1^+(t)$ and t = 1 year.

The system of state variables can be simplified by succesive substitution. For example:

$$x_5(t+1) = b_{55}x_5(t) + bk_1^+(t-4)$$

where $b = b_{54}\, b_{43}\, b_{32}\, b_{21}$

Thus we have one state variable, one time delay and t = 1 year.

If we choose time period equals 5 years, then we can even eliminate time delay. The state equation then reduces to:

$$x_5(t+1) = \bar{b}_5 x_5(t) + \bar{\bar{k}}\,(t), \text{ where}$$

* Note: We consider different production of mature trees from 5 to 10 years (age of trees)

$\bar{k}(t)$ = the number of planting during 5 year period;

$\bar{b}_5$ = shows what proportion of trees, planted during a 5 years period, will be producing.

Next we present the implemented model

Let,

τ = (78, ..., 78 + T) be the set of time periods, T is the planning horizon;

J = (79, 80, ..., 85) be the set of years when the parcels were conditioned to be planted;

I = (69, 70, ..., 85) be the set of years when trees planted;

K = (1, ..., 4) be the set of types of parcels, according to their degree of erosion;

Parameters:

C_{ij}^{kt} = additional investments at year t, $t \in \tau$, related to reconstructions at year j, $j \in J$, for 1 ha. of parcel type k, $k \in K$, planted at year i, -- $i \in I$, and $t \geq j > i$

a_{ij}^{kt} = production at year t, $t \in \tau$, for 1 ha. planted at year i, $i \in I$, for -- parcel type k, $k \in K$, reconstructed at j, $j \in J$;

c_{ij}^{kt} = processing cost at year t, $t \in \tau$, for 1 ha. of parcel of type k, $k \in K$, planted at i, $i \in I$, and reconstructed at j, $j \in J$;

$c_{ij}^{k} = \sum_{t=79}^{95} c_{ij}^{rt}$ integrated cost related to processing 1 ha. of parcel of type k, $k \in K$, planted at i, $i \in I$, and reconstructed at j, - $j \in J$;

c_j^t = processing cost at year t, $t \in \tau$, related to the utilization of 1 ha. of parcels planted at j, $j \in J$;

p^t = price for 1 Ton. purchased production at year t, $t \in \tau$;

s^{ki} = area for k type parcels planted at i, $i \in I$;

s^j = area of new parcels ready to be planted at year j, $j \in J$;

Q^t = sinking funds at year t, $t \in \tau$, for the factory processing the fruits;

q^T = sinkings funds (for unity of capacity) for the enlargement of the factory at year T, $T \in \tau$;

M = actual processing capacity for the factory at the beginning of the --- planning period;

Decision variables:

x_{ij}^{k} = area for k type parcels, planted at year i, $i \in I$, and reconstructed - at j, $j \in J$;

x_j = area planted at year j, $j \in J$;

y^t = volume of fruits produced at year t, $t \in \mathcal{T}$;

z^T = enlargement of the capacity of the processing factory at T years;

v^t = profit obtained by fruit production and processing at year t, $t \in \mathcal{T}$;

N^t = investments at year t, $t \in \mathcal{T}$; for the enlargement of social infraestructure;

Constraints:

1.- $$\sum_{j=78}^{85} x_{ij}^{k} = s^{ki}, \; i \in I; \; k \in K;$$

condition constraining k type parcels planted at i, $i \in I$;

2.- $$x_j = s^j, \; j \in J;$$

condition constraining new parcels planted at j, $j \in J$;

3.- $$p^t y^t - \sum_{j=79}^{t} \left(\sum_{i \in I} \sum_{k \in K} (c_{ij}^{kt} + c_j^t) x_j \right) - \sum_{t'=79}^{t} q^{t'} z^{t'} - v^t = Q^t$$

$t', t \in \mathcal{T}$;

balance conditions to form profits resulting from production, processing - and purchase of the fruits at year t, t ;

4.- $$\sum_{j=79}^{t} \left(\sum_{i \in I} \sum_{k=1}^{4} a_{ij}^{kt} x_{ij}^{k} + a_j^t x_j \right) - y^t = 0, \; t, \; t \in \mathcal{T};$$

conditions to produce the volume of fruits at year t;

5.- $$y^t - \sum_{t'=79}^{t} z^{t'} \leq M; \; t', \; t \in \mathcal{T};$$

conditions for the factory to process the volume of fruits produced;

It is demanded to maximize the general profit for the planning period. It --- means:

$$\sum_{t=79}^{95} p^t y^t - \sum_{j=79}^{85} \left(\sum_k \sum_i c_{ji}^k x_{ji}^k + c_j x_j \right) - \sum_{t'=79}^{85} q^{t'} z^{t'} - Q \longrightarrow \max$$

The model was succesfully implemented and is actually used, mainly, for crop-prediction and resource allocation problems within the citrus enterprise "Isla de la Juventud".

PLANNING LON RANGE LIVESTOCK

Next we present the general ideas (CSAKI-76) of a DLP model for a livestock production system, and the implemented version for our particular case (MO-RIN-DIPOTET-81).

Let

$I = (1, \ldots, s)$ be the set of differents type of animals;

$\mathcal{T} = (1, \ldots, T)$ be the set of time periods, T is the planning horizon;

$x_i(t)$ = the number of animals of type i, $i \in I$, at year (period) t, $t \in \mathcal{T}$;

$k_1^+(t)$ = the number of animals of type i, $i \in I$, purchased at period t, $t \in \mathcal{T}$;

$k_1^-(t)$ = the number of animals of type i, $i \in I$, sold at period t, $t \in \mathcal{T}$;

a_{ij} = the coefficient which shows what proportion of animals of type j, --- $j \in J$, will progress to type i, $i \in I$, in the succeding period.

Then we can write the state equations for the livestock subsystem as:

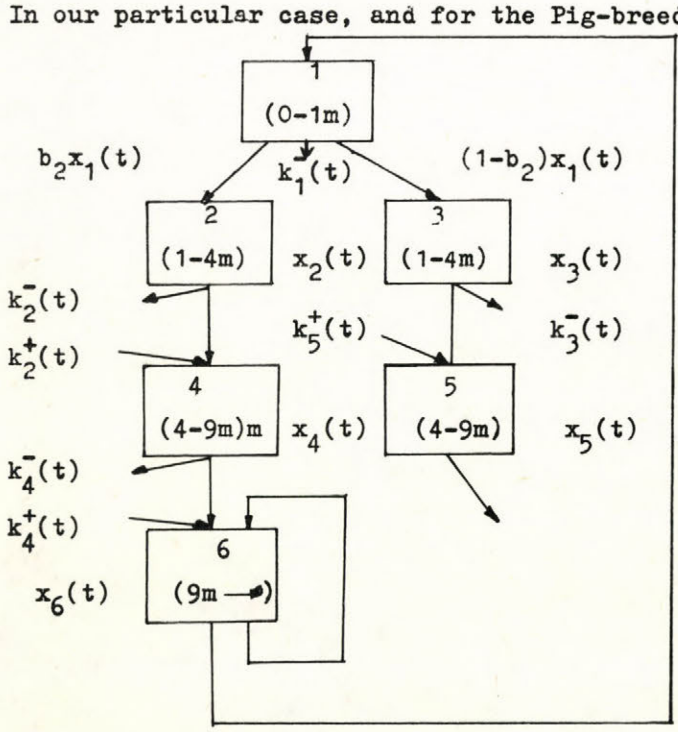
$$x_i(t+1) = \sum_{j=1}^{s} a_{ij}x_j(t) + k_i^+(t) - k_i^-(t) \qquad (1)$$

or in matrix form

$$x(t+1) = Ax(t) + k^+(t) - k^-(t)$$

Here $x(t) = (x_1(t), \ldots, x_s(t))$ is the vector of state variables; $k^+(t) = (k_1^+(t), \ldots, k_s^+(t))$ and $k^-(t) = k_1^-(t), \ldots, k_s^-(t))$ are vectors of -- control variables.

In our particular case, and for the Pig-breeding subsystem example we have:



t = 1 month (time unit)

$$x_1(t+1) = a_{61}x_6(t)$$

$$x_2(t+1) = a_{12}x_1(t) - k_1^-(t)\, b_2 + (1-a_{24})x_2(t)$$

$$\vdots \qquad \vdots$$

$$x_6(t+1) = a_{46}x_4(t) + a_{66}x_6(t) + k_6^+(t+1) - k_4^-(t)$$

<u>State variables:</u>

$x(t) = (x_1^t, \ldots, x_6^t)$

Control variables

$$k^-(t) = (K_1^-(t), \ldots, k_4^-(t))$$
$$k^+(t) = (k_2^+(t)_1, k_3^+(t), k_4^+(t))$$

Values for a,b and constraints equations, depend on local conditions and production technology (MORIN-81).

In our case, we obtained the optimal flock structure at time to (for x_1 known) using natural, capacity, food, manpower and technological constraints and LP - program package.

With this structure as initial conditions we derived the time (year) recurrency $x(t) \rightarrow x(t+1)$, $x(t+1) = Ax(t) + k^+(t) - k^-(t)$ (for fixed local conditions - and technology, it means constraints) trying to maximize the flock ---------- $(z = \sum_{\substack{i=1 \\ t \in \tau}}^{s} x_i(t))$ keeping its internal optimal structure.

For the time being, the accuracy of the results we obtained with this model is enough, nevertheless we are working on different type of models, for this same livestock system.

PROBLEMS ON SOCIO-ECONOMICAL OBJECTS MICROLOCALIZATION

The elements of this problem are:

- a set J = (1, ..., n) of raw materials sources;
- a set I = (1, ..., m) of points where it is possible to place the enterprises for processing the raw materials;
- a known function $b: J \rightarrow R$, whose values b_j represent the volumes of raw materials coming from the sources j, $j \in J$;
- an unknown (a priori) function $X: I \rightarrow R$ whose value X_i is the capacity of -- point i, $i \in I$, for processing raw material;
- a function $x: I \times J \rightarrow R$ such that x_{ij} is the quantity of raw material from source j, $j \in J$, to be elaborated in point i, $i \in I$;
- a known family $(g_i : R \rightarrow R)_{i \quad I}$ of functions such that

$$g_i(X_j) = \begin{cases} 0 \text{ if } i \neq j \\ \text{building and maintenance cost for the enterprise } i,\ i \in I, \text{ depending on capacity } X_i. \end{cases}$$

- a known function $T: I \rightarrow R$ whose value T_i is the building cost for object- i, $i \in I$;
- a known function $K: I \rightarrow R$ for the processing cost of raw material unity in the object i, $i \in I$;
- a function $c: I \times J \rightarrow R$ transportation cost of raw material from j, $j \in J$,- to i; if $d: I \times J \rightarrow R$ is the distance matrix for points i and j, then, -- generally, the transportation point is proportional ($p: R \rightarrow R$) to the -- distance and $c_{ij} = p \cdot d_{ij}$;
- a function $P : 2^I \rightarrow R$ defined on the set of parts $w \subset I$

$$P(w) = \sum_{\substack{i \in I \\ j \in J}} c_{ij} x_{ij} + \sum_{i \in w} g_i(X_i)$$

  P(w) is interpreted as the cost of construction, maintenance and transport for objects at ponnts i, $i \in w$.
- the actual shape of g_i is $g_i(X_i) = (K_i X_i + T_i)$. Sign (X_i) it is possible to show (Figueroa-Jachaturov 78) that P(w) may be calculated in the following way:

$$P(w) = \sum_{j \in J} b_j \min_{i \in w} (C_{ij} + K_i) + \sum_{i \in w} T_i$$

The problem now is to calculate an $\alpha \subset I$ such that $P(\alpha) = \min_{w \in I} P(w)$ with the following natural constraints $b_j = \sum_{i\in\alpha} x_{ij}$ (all raw materials are distributed to the enterprises)

$$x_{ij} \geq 0$$

$$X_i = \sum_{j\in J} x_{ij}$$ (the capacity of point i is -- completely used)

There are algoritms (Jachaturov-78) for the exact solution of the former problem.

In our particular case, we must offer recomendations for building some socio-economical objects under the following conditions (Jachaturov-Figueroa 78):

$$P(w) = \sum_{j\in J} b_j \min_{i\in w} (l_{ij} \cdot p + K_i) + q \sum_{i\in w} T_i;$$

Where p and q are some kind of fuzzy parameters with the following meaning:

p is the transportation cost for the production unity to the unity of distance;

q is the normative coefficient for efficiency in capital investments.

$\left| l_{ij} \right|$ is a known matrix giving the distances between points i, $i\in I$, and j,-- $j\in J$, respectively.

The available information about p and q may be graphically represented as -- fuzzy sets originated by statistical sources (or others)

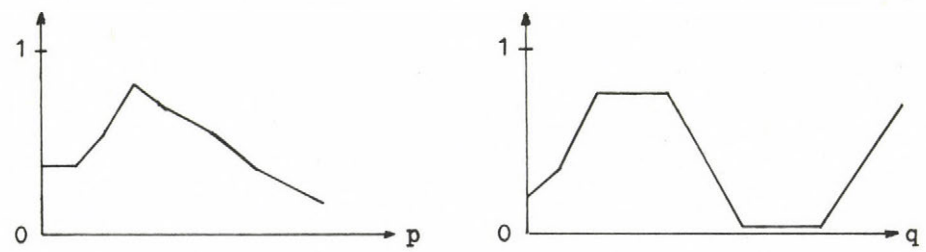


Fig.8

We also consider the case when there is no information about p or q. Then - the task of "more rational, instead of optimal, microlocalization of the objects", nust be solved.

We suppose, simplifying, $(\forall i \in I)$, $K_i = K$, $T_i = T$.

Then, $P(w) = p \sum_{j\in J} \min_{i\in w} l_{ij} + K \sum_{j\in J} b_j + q \left| w \right| T.$

We next investigate the task solution for one parameter.

We investigate for q fixed, for example, q = 1.

Then $P(w) = (\sum_{j \in J} \min_{i \in w} l_{ij})\, p + |w|\, T + K \sum_{j \in J} b_j$

- We first determine an interval for parameter p, $p \in [A, B]$, where:
  if $p < A$ the solution has cardinal minimum not null;
  if $p > B$ the solution has cardinal maximum (it is needed to build in all -- points).
- We solve several systems of linear equations to find subintervals (in p) -- where the solutions do not change within it. We obtain, for example

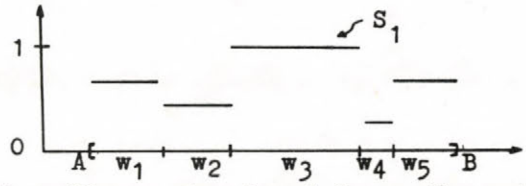


Fig.9

  together with a "fuzzy structure" S_1 on the set of solutions $\{w_1, \ldots, w_5\}$ such that the maximum degree of pertenence belongs to the more stable --- (for parameter variation) set;
- A refinement of the former partition is calculated. The subinterval ----- (l_i, l_{i+1}) corresponding to the solution w_i is divided into subintervals - $\lambda_j, \lambda_{j+1}, (\lambda_i = l_i, \lambda_r = l_{i+1})$, $j = 1, \ldots, r$; where the raw material - supply from the sources to the processing plants do not change. We obtain also a fuzzy structure on the subintervals.

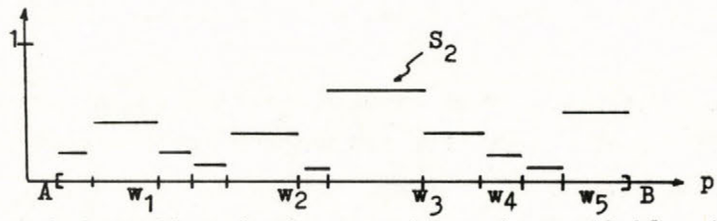


Fig. 10

- If some a priori information about parameter p is available, it may be a - fuzzy one.

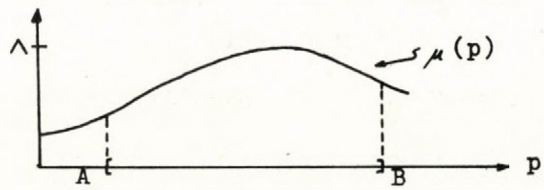


Fig. 11

We take its restriction (see Jachaturov-Figueroa 79) to $[A, B]$, $f \wedge \mathcal{U}_{[A,B]}$. We may propose, for management decision making, the algebraic product of all fuzzy structures considered extended to 2^I

$$R(w) = \begin{cases} 0 \text{ if } w = w_i \text{ for } i = 1, \ldots, 5 \\ (S_1 . S_2 . \bar{\mu})(w_i) = S_1(w_i) . S_2(w_i) . \bar{\mu}(w_i) \end{cases}$$

where $\bar{\mu}(w_i) = \max_{p \in [l_i, l_{i+1}]} \bar{\mu}(p)$

It is possible to show that there is an interval $[\underline{p}, \bar{p}]$ such that, if $p \leq \underline{p}$ then only one object must be built and, if $p \geq \bar{p}$ then it is needed to build objects in all available places. We are then interested in the interval $[\underline{p}, \bar{p}]$.

We cannot (due to the high dimensionality of the job) calculate a straight-line for each $w \subset I$ such as

$$P(w) = \left(\sum_j \min_{i \in w} l_{ij}\right)p + |w|\, T + K \sum_j b_j$$

and to consider the envelope (convex, piecewise linear curve) of that family of straight lines.

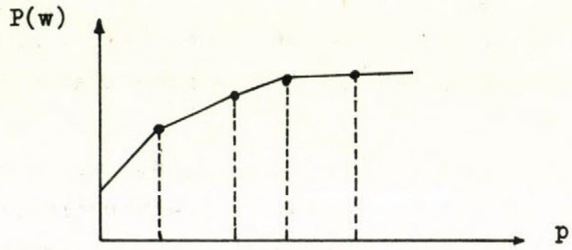


Fig. 12

With this approach we could obtain a partition for interval $[\underline{p}, \bar{p}]$ in subintervals where the optimal solution w could be constant.

To avoid the former difficulties we applied a method which consisted in the a priori determination of a very thin and uniform partition of the subinterval $[\underline{p}, \bar{p}]$. For each value of p corresponding to the nodes of the partition we calculate (Jachaturov-76) the global minimum for function P(w). In this case we developed (Jachaturov-Figueroa 78) an algorithm for searching local minimum and, afterwards we select the "best" one.

In that way we obtain a partition of $[\underline{p}, \bar{p}]$ in stability subintervals of the minimum of p.

Supported by heuristical criteria we assign, in that way, to all $w \subset I$ one priority. For example, we can assign one priority proportional to the measure of the stability respecting the variation of p. The $w \subset I$ outside the partition receives priority o. Thus, one fuzzy set structure on $\Omega = 2^I$ is derived which solves our task.

We obtained the solution for q = 1. This allows us to determine a partition of the first quadrant in the following way,

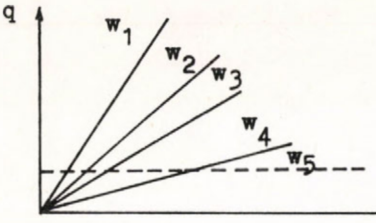


Fig. 13

Where each area of the plane is a stability area for the solution. Thus, - if a pair is known, we can derive the subset which allows us to obtain the minimum. When q diminishes and the socio-economical objects are cheaper (the building); the solution may change, increasing the number of objects (for p-fixed). If q is fixed and transport cost is reduced, we decrease the number of objects.

When we have the solution as a priority structure on the power set of I ---- (fuzzy subset of I), for each subinterval $\left[l_k, l_{k+1}\right] \subset \left[\underline{p}, \bar{p}\right]$ corresponding to a not null priority subset, we then obtain a partition of $\left[l_k, l_{k+1}\right]$ --- into stability subintervals for the assignation of elements of J to those of w_k.

If $\underline{C}_{ij} = l_{ij} \cdot l_k$ and $\bar{C}_{ij} = l_{ij} \cdot l_{k+1}$; then,

$$P(w_k) = \sum_{j \in J} b_j \min_{i \in w_k} \underline{C}_{ij} + (\bar{C}_{ij} - \underline{C}_{ij}) + \sum_{i \in w_k} T_i ;$$

Where, for each $j \in J$, the function $\min_{i \in w_k} \left[\underline{C}_{ij} + \lambda (\bar{C}_{ij} - \underline{C}_{ij})\right]$ is the envelopment of the straigh lines of the following type

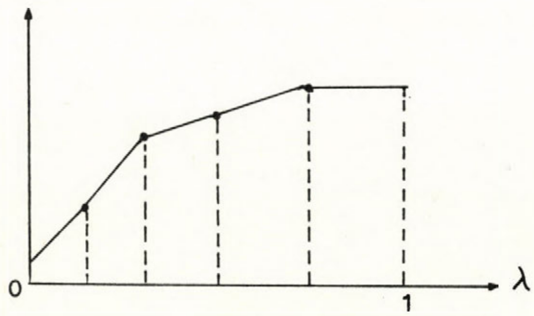


Fig. 14

It is not difficult to show (Figueroa-79) that the sum of all the former --- funcions, $P(w_k)$, is a function of the same type.

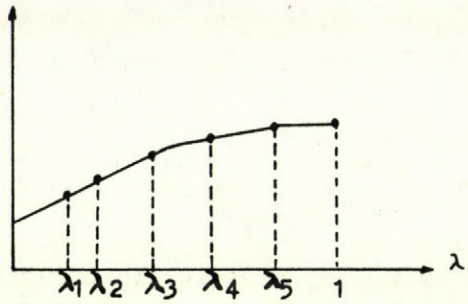


Fig.15

It is also possible to show that on each subinterval $[\lambda_k, \lambda_{k+1}]$ the assignations are constants.

Now we can determine (for each $w \subset I$ with its priority a priority structure on the set of their possible assignations, as we have done before with the - subsets $w \subset I$.

For simplifying the results, we list only the support of the fuzzy subset -- determined by the priority structure. In the listing, we present several -- (one for each $w \subset I$ with positive priority tables composed of two columns -- one for asignation and the other for priority and as many rows as there are assignations with no null priority.

The former algorithms have been applied (Figueroa-79) to the microlocaliza-- tion fo some socio-economical objects in the Island of Pines.

DISCRETE MODELS IN REGIONAL PLANNING

The elements of the general problem are:

- a set J = (1, ..., n) of raw materials sources;
- a set I = (1, ..., m)of points where it is possible to place the enterprises for processing the raw materials;
- a set $\mathcal{T}$= (1,2, ..., T) of time periods, where T is the planning period;
- a known function b: J ⟶ R, whose values b_j^t represent the volumes of raw materials coming from the sources j, $j \in J$, at time $t \in \mathcal{T}$;
- an unknown (a priori) function X: I ⟶ R whose value X_i^t is the capacity of point i, $i \in I$, for processing raw material al time $t \in \mathcal{T}$;
- a function x: I x J ⟶ such that x_{ij}^t is the quantity of raw material from source j, $j \in J$, to be elaborated in point i, $i \in I$, at time $t \in \mathcal{T}$;
- a function c: I x J ⟶R transportation cost of raw material from j, $j \in J$, to i, $i \in I$, at time $t \in \mathcal{T}$; if d: I x J ⟶ R is the distance matrix for points i and j, then, generally, the transportation point is proportional (p: R ⟶R) to the distance and $c_{ij} = p.d_{ij}$;
- a function x: I x J ⟶R such that x_{ij}^t is the quantity of raw material from source j, $j \in J$, to be elaborated in point i, $i \in I$, at time $t \in \mathcal{T}$;
- a known function T: I ⟶R whose value T_i is the building cost for object i, $i \in I$;
- a known function K: I ⟶R whose value K_i^t is the processing cost of raw-material unity in the object i, $i \in I$, at time $t \in \mathcal{T}$;
- $g_i(X_i^t)$ are the building and processing cost for the enterprise i, $i \in I$, at time t, $t \in \mathcal{T}$, depending on capacity X_i;

Let $X_i^t = \sum_{j \in J} x_{ij}^t$ then the task of optimal object micolocalization for a given region may be formulated as:

to determine, $\min_{x_{ij}^t} \sum_{i \in I} \sum_{j \in J} \sum_{t \in \mathcal{T}} c_{ij}^t \, x_{ij}^t + \sum_{i \in I} \sum_{t \in \mathcal{T}} g_i(X_i^t)$;

the constraints are:

$$\sum_{i \in I} x_{ij}^t = b_j^t$$

$$X_i^t = \sum_{j \in J} x_{ij}^t \leq a_i^t$$

$$x_{ij}^t \geq 0$$

If functions $g_i(X_i^t)$ are linear, then we face a transport dynamic task and to solve it we apply the linear programming methods. Nevertheless, generally, these functions $g_i(X_i^t)$ are not linear, but discrete discontinuos ones, difficulting the solution for this task in the general case.

If $g_i(X_i^t) = (K_i X_i^t + C_i)$ Sign X_i^t (DIPOTET-81) then our task will be reduced to:

$$\min_{x_{ij}^t} \sum_{i \in I} \sum_{j \in J} \sum_{t \in \tau} (c_{ij}^t + K_i^t)\, x_{ij}^t + \sum_{i \in I} T_i \text{ Sign } X_i^t$$

$$\sum_{i \in I} x_{ij}^t = b_j^t$$

$$\sum_{j \in J} x_{ij}^t \geq a_i^t;\ x_{ij}^t \geq 0$$

This task is a multi-extremes one in non-linear programming. It may be solved using combinatorical methods, using the "branch and bound" method. However, for using these methods in medium size problems, powerful computers are needed.

For long range planning, in our case, it is possible to use a simplified model not considering capacity (X_i^t) constraints.

Then, our task will be the following:

to determine,

$$\min_{x_{ij}^t} \sum_{i \in I} \sum_{j \in J} \sum_{t \in \tau} d_{ij}^t\, x_{ij}^t + \sum_{i \in I} T_i \text{ Sign } X_i^t$$

$$\sum_{i \in I} x_{ij}^t = b_j^t,\quad x_{ij}^t \geq 0$$

were $d_{ij}^t = c_{ij}^t + K_i^t$

Next we present the combinatorical version for the former problem statement.

Let $w \subset I$ be a subset where we suppose must be buil the objects to microlocalize.

Then, on the set of all subsets $w \subset I$ it is possible to define function $P(w)$ in the following way:

$$P(w) = \min_{x_{ij}^t} \sum_{i \in w} \sum_{j \in J} \sum_{t \in \tau} d_{ij}^t\, x_{ij}^t + \sum_{i \in w} T_i;$$

$$\sum_{i \in w} x_{ij}^t = b_j^t$$

$$x_{ij}^t \geq 0,\ i \in w$$

There are not constraints linking the variables by t, then we may write:

$$P(w) = \sum_{t\in \mathcal{T}} \min_{x_{ij}^t} \sum_{i\in w} \sum_{j\in J} d_{ij}\, x_{ij}^t + \sum_{i\in w} T_i$$

There are not constraints of the type $X_i^t \leq a_i^t$ then it is possible to write:

$$P(w) = \sum_{t\in \mathcal{T}} \sum_{j\in J} b_j^t \min d_{ij}^t + \sum_{i\in w} T_i$$

$$P(w) = \sum_{t\in \mathcal{T}} \sum_{j\in J} \min_{i\in w} b_j^t\, d_{ij}^t + \sum_{i\in w} T_i$$

To solve this task it is needed: to buit T matrix $\left\| b_j^t\, d_{ij}^t \right\|_{mxn}$; then, to --- find $\sum_j \min b_j^t\, d_{ij}^t$ for every t, $t \in \mathcal{T}$; then to sum up (index t) and to add - $\sum_{i\in w} T_i$.

In the most simple case, when $d_{ij}^t = d_{ij}$ (it means $c_{ij}^t = c_{ij}$; $K_i^t = K_i$) it is - possible to write:

$$P(w) = \min_{x_{ij}^t} \sum_{i\in w} \sum_{j\in J} d_{ij} \sum_{t\in \mathcal{T}} x_{ij}^t + \sum_{i\in w} T_i$$

We have not constraints $X_i^t \leq a_i^t$, then x_{ij}^t for every t must take value 0 or - (exclusive) b_j^t, because of constraints.

$$\sum_{i\in w} x_{ij}^t = b_j^t$$

Then, to determine the P(w) value it is possible to use the following

$$P(w) = \sum_{j\in J} \min d_{ij} \left(\sum_{t\in \mathcal{T}} b_j^t\right) + \sum_{i\in w} T_i$$

Now, the computations to find P(w) are very simplified because the task is - now a not dynamic one and it is possible to calculate

$$P(w) = \sum_{j\in J} \min_{i\in w} d_{ij}\, \bar{b}_j + \sum_{i\in w} T_i; \qquad \text{(I)}$$

here $\bar{b}_j = \sum_{t\in \mathcal{T}} b_j^t$ is only once calculated before computing the P(w) values - for every $w \subset I$.

We remark that in this simple case P(w) is related to distance and building-cost and (I) fulfill (for the moment) the requirements of our problem (ob--- jects microlocalization a developing region).

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Моделирование социально-экономического развития некоторого нового сельскохозяйственного района

Перфекто Дипотет

В работе дается общая концепция информационной системы поддерживающей комплексное развитие в отсталых областях развивающихся стран. Также описываются математическим программированием решаемые модели для некоторых конкретных подсистем /проектирование выращивания многолетных, размещение социально-экономических объектов, и т.д./.

Egy új mezőgazdasági terület társadalmi-gazdasági fejlődésének modellezése

A dolgozat egy, a fejlődő országok elmaradottabb területi egységeinek komplex gazdasági fejlesztését támogató információs rendszer koncepcióját vázolja fel. A szerző az általános leirás mellett több konkrét részrendszerre /évelőtermesztés tervezése, társadalmi-gazdasági objektumok elhelyezése, stb/ matematikai programozással megoldható modellt is közöl.