Working Paper

SOME CONSIDERATIONS ABOUT THE CONSTRUCTION OF A SYSTEM OF REGIONAL MODELS

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INTRODUCTION

This paper is elaborated taking into account the following basic initial assumptions:

-- The region has to be modeled as an integrated system with common input-output on the basis of man-machine interaction procedures.

-- The feature characteristics of the existing economic and social management mechanism are considered: the separate region is not independent, but a closely connected unit with the national system.

-- Modeling of the separate region is to serve as a standard for modeling of all regions in the country with organic connection with the modeling on a national level.

-- Special attention is paid to the consistency and feature charactertistics of the internal regional production links within a common calculation cycle.

INTERRELATIONS BETWEEN THE SYSTEM OF MODELS FOR THE REGION AND THE NATIONAL SYSTEM OF MODELS

The common input and output of the system of models for the separate region is determined by the concrete production links of these models with the intersectorial and interregional/intersectorial models on a national level and with the intersectorial models on a sectorial level.

Without analyzing the approach used to solve national models, it is necessary to underline here the following, from a theoretical viewpoint.

The intersectorial model on a national level is connected with direct and feedback with the interregional/intersectorial model. Solving the latter (which considers the spatial factors of the efficiency) we will balance the products (activities) between all regions in the country. Hence, the input of the separate region (which is the output of the interregional/intersectorial model) will be the total volume and structure of the regions:

$$X_i^r(t) + \sum_{p \neq r} X_i^{pr}(t) = \sum_j a_{ij} X_j^r(t) + \sum_j b_{ij} \, \Delta \, X_j^r(t) + \alpha Z^r(t) + \sum_{p \neq r} X_i^{rp}(t) \quad , \qquad (1)$$

where:

X_i = total volume of product i;
r = the region under analysis;
p = the other regions in the country;
a_{ij} = technological coefficients;
b_{ij} = production funds coefficients;
Z = non-productive consumption
(α = assortment coefficient).

The connection of the separate region models with the sectorial models is determined by the fact that direct and feedback exists in the process of the optimization of the sectorial mdoels and between the interregional/intersectorial model and the intersectorial model on a national level. Thus, from the viewpoint of the separate region the different products within the region belong to different sectors which have to be optimized in a separate way in terms of own local sectorial criterion. At the same time from the viewpoint of the separate sector, the sectorial optimization has to be determined for all regions of the country, but not only for the separate regions under analysis. Hence, the links between the separate region model and the sectorial models are indirect and they go through the interregional/intersectorial model. Only an information link exists between the sectorial models and the model of the separate region. This can be seen in Figure 1.

The situation in practice differs from the above theoretical statement due to the following:

-- The links on a national level are strongly aggregated and only a part of the products is specified by volume, by regions and by subregions, of the region. The other part of the products may be: non-specified products by volume in sectors aspect (usually this is for production with local importance for the region); non-specified products by subregions of the region; combination of the first and second.
-- The regional body has direct management functions regarding the production of local importance.

The above practical considerations have to reflect on the intraregional model (1) which is to be modified through the differentiation of the production of national and local importance and by subregions of the region:

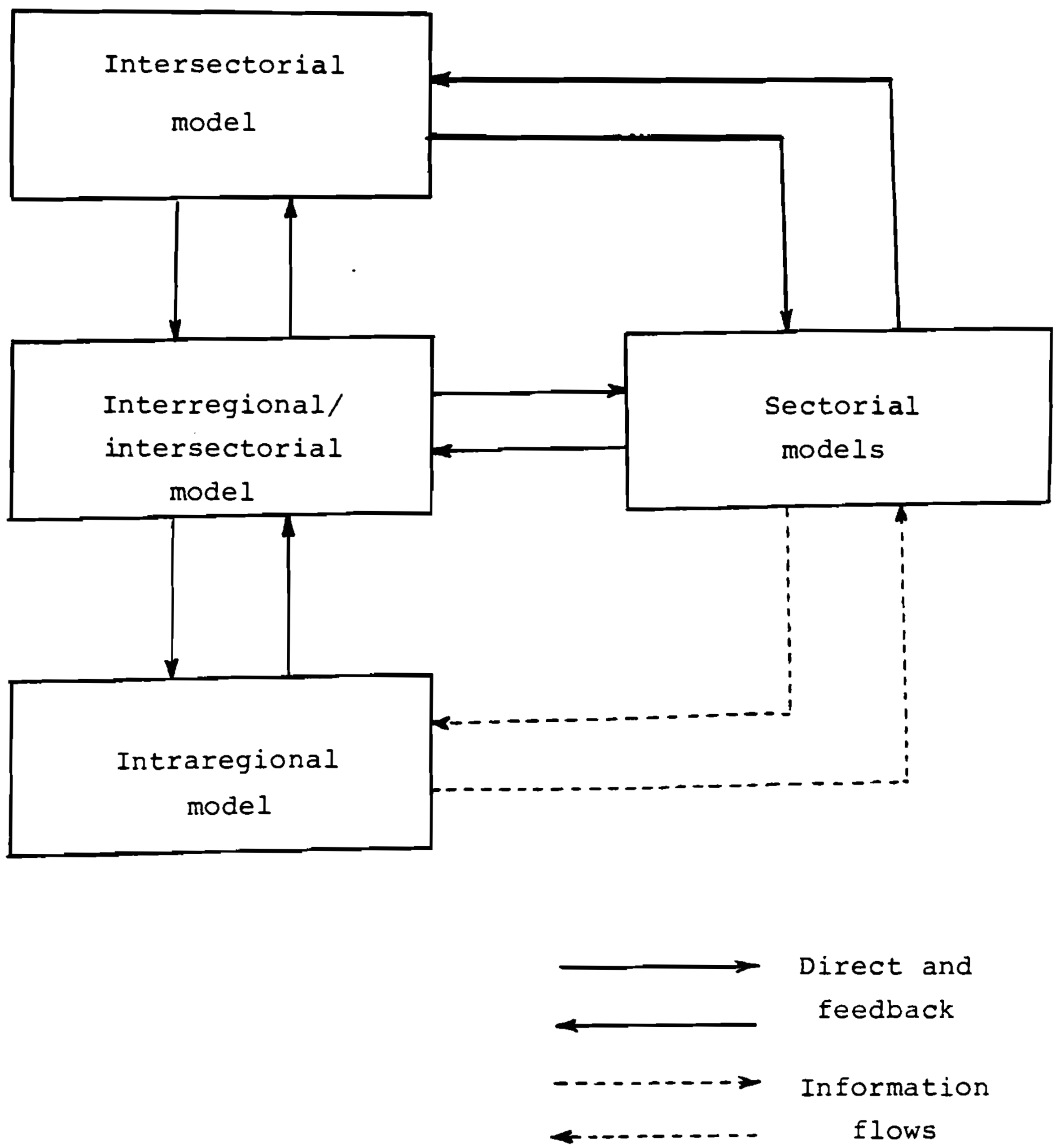

Figure 1. Interactions between the National and Regional Models.

$$\hat{X}_{ir}(t) + X_{ir}(t) + \sum_{p \neq r} \hat{X}^{I}_{ipr}(t) = \sum_j a_{ij}\hat{X}_{jr}(t) + \sum_j a_{ij}X_{jr}(t)$$

$$+ \sum_j b_{ij}\Delta\hat{X}_{jr}(t) + \sum_j b_{ij}\Delta X_{jr}(t) \qquad (2)$$

$$+ \alpha_i \hat{Z}_r(t) + \alpha_i Z_r(t) + \sum_{p \neq r} \hat{X}^{E}_{irp}(t) \quad ,$$

where:

$\hat{}$ = symbol for the production of national importance exogenously assigned by the intersectorial and the interregional/intersectorial model;

I = import;

E = export;

whence the following initial constraints can be prescribed for the separate region:

-- assigned volume of the i-th production of national importance:

$$\hat{X}_{ir}(t) = N(t) \quad ; \qquad (3)$$

-- assigned volume of import of the i-th product:

$$\sum_{p \neq r} \hat{X}^{I}_{ipr}(t) = I(t) \quad ; \qquad (4)$$

-- assigned volume of export of the i-th product:

$$\sum_{p \neq r} \hat{X}^{E}_{irp}(t) = E(t) \quad ; \qquad (5)$$

-- assigned volume of production for non-productive consumption:

$$\alpha_i \hat{Z}_r(t) = H(t) \quad ; \tag{6}$$

-- assigned volume of resources for current productive consumption:

$$\sum_j a_{ij} \hat{X}_{jr}(t) = A(t) \quad ; \tag{7}$$

-- constraints for maximum capital investments:

$$\sum_j b_{ij} \hat{X}_{jr}(t) \leq B(t) \quad ; \tag{8}$$

-- constraints for maximum quantity of labor force by qualification groups q (v_{qj} = labor coefficients):

$$\sum_j v_{qj} X_{jr}(t) \leq L(t) \quad ; \tag{9}$$

-- constraints for maximum volume of gross wage (ν_{qi} = normative wage by q-th type of qualification in the i-th sector):

$$\sum_i v_{qi} \nu_{qi} X_{jr}(t) \leq V(t) \quad . \tag{10}$$

The differentiation of the products (activities) respectively of national and local importance is absolutely necessary to be made for the modeling of regional development due to the following considerations.

-- The production volume of national importance $\hat{X}_{ir}$, $\hat{X}^{I}_{ipr}$ and $\hat{X}^{E}_{irp}$ and the financial ($\hat{F}_i$) and labor ($\hat{L}_i$) supply have to be assigned exogenously to the separate region and they cannot be subject to optimization within the region.

Otherwise, the optimization by local criterion within the region under analysis will always provoke an imbalance within the remaining regions in the country. The latter is due to the different kinds of criteria used on a national and regional level and to the different scope of the expenditures and the efficiency on a national and regional level.

-- The products (activities) which are simultaneously of national and local importance require that the production volume of the local importance only has to be optimized in terms of local criteria. The part of production volume of national importance has to be assigned exogenously to the region.

The analysis made above allows us to specify the input of the system of models for development of the separate region (shown in Figure 2). The output of the regional model (including the feedback to the models on a national level) might be specified after a linkage of the subsystem models in an integrated system of models within the region.

DESCRIPTION OF THE DEVELOPMENT OF THE SEPARATE SUBSYSTEMS AND THEIR LINKS AT THE INITIAL STAGE OF THE OPTIMIZATION CYCLE

Initial Stage (0) - Description of the Agriculture Development and Links

Agriculture as a subsystem within the region (including a processing industry) forms its income at the initial stage as follows:

$$\underbrace{p_j \hat{x}_{jr}(t) + p_j x_{jr}(t) + \sum_{r \neq p} p_j \hat{x}^E_{jrp}(t)}_{\text{Revenue}} = \underbrace{\sum_i \sum_m a_{ji} p_i x_{jm}(t)}_{\text{Expenditures}}$$

$$+ \underbrace{\sum_j \sum_m v_{qi} \nu_i x_{jm}(t) + \sum_i \sum_m c_j x_{jm}(t)}_{\text{Expenditures}} \qquad (11)$$

$$+ \underbrace{\sum_i \sum_{r \neq p} p_i \hat{x}^I_{jpr}(t)}_{\text{Expenditures}} + \underbrace{\alpha \sum_j \sum_m b_{ji} x_{jm}(t)}_{\text{Reduced Capital Investments}} ,$$

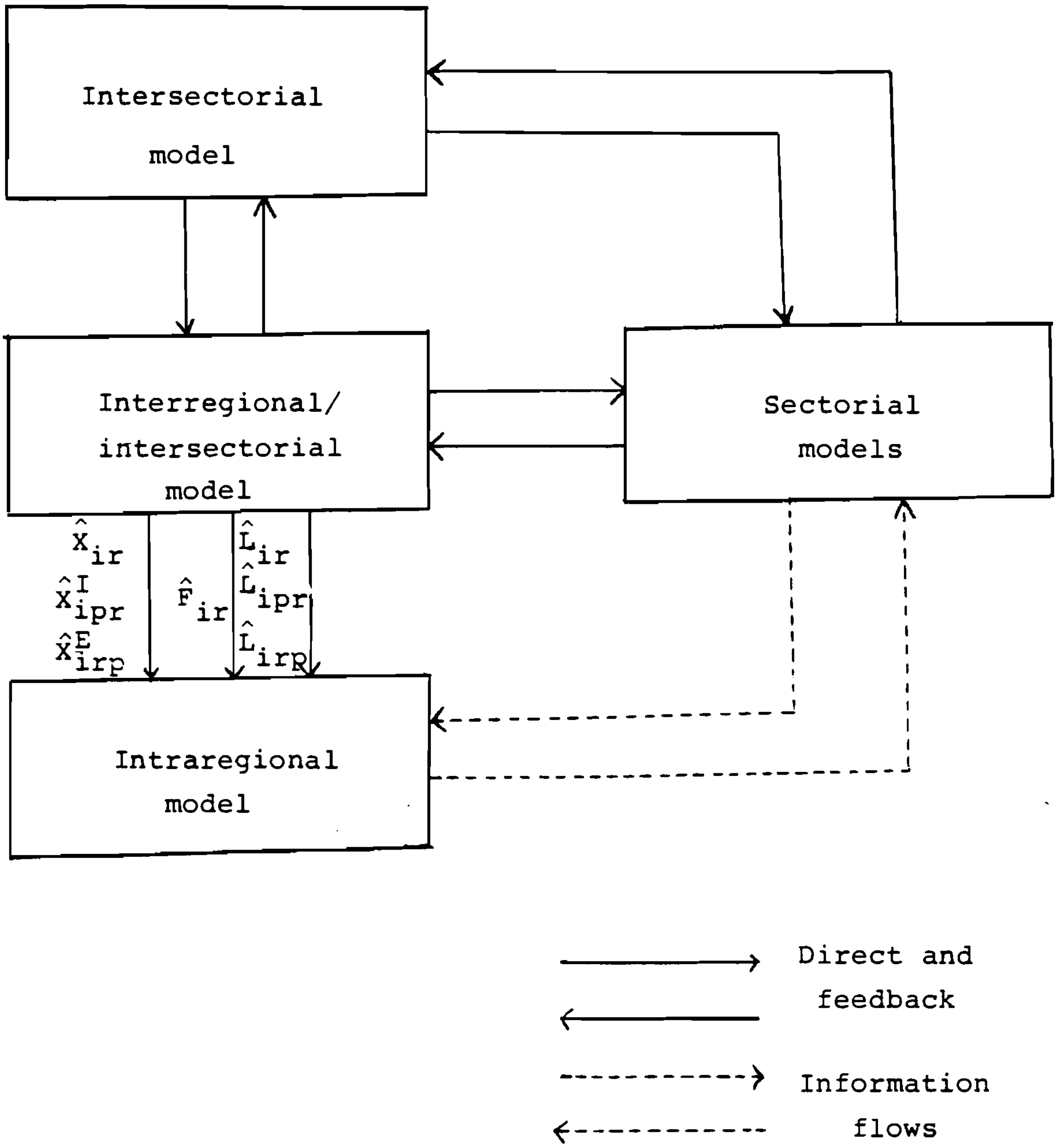

Figure 2. Regional Inputs from the National Models

where

$p_j x_j$ = volume of j-th product at corresponding prices;

m = subregions of the region;

$c_j x_{jm}$ = volume of j-th intermediate product;

α = coefficient for reducing the capital investments to annual costs.

The optimization problem for agriculture which stems from the problem mentioned above requires that (see Figure 3):

-- The production volume of national importance $\hat{x}_{jr}$ and $\hat{x}^E_{jrp}$ have to be optimized with respect to their territorial distribution only. This is necessary in the cases when the production optimization on a national level treats the region as one point, but not by subregions of the region. The factors of productive (technological) character cannot be subject to optimization within the region, because they have been considered on a national level of optimization.

The model for the region will appear as follows:

$$\sum_i \sum_m \sum_l (d_{ilm} + \alpha K_{ilm}) \hat{x}_{ilm}(t) \rightarrow \min \quad , \qquad (12)$$

where

l = transportation modes;

d = current transportation expenditures;

K = capital investments for transport development;

α = coefficient for reducing capital investments to the current transportation costs.

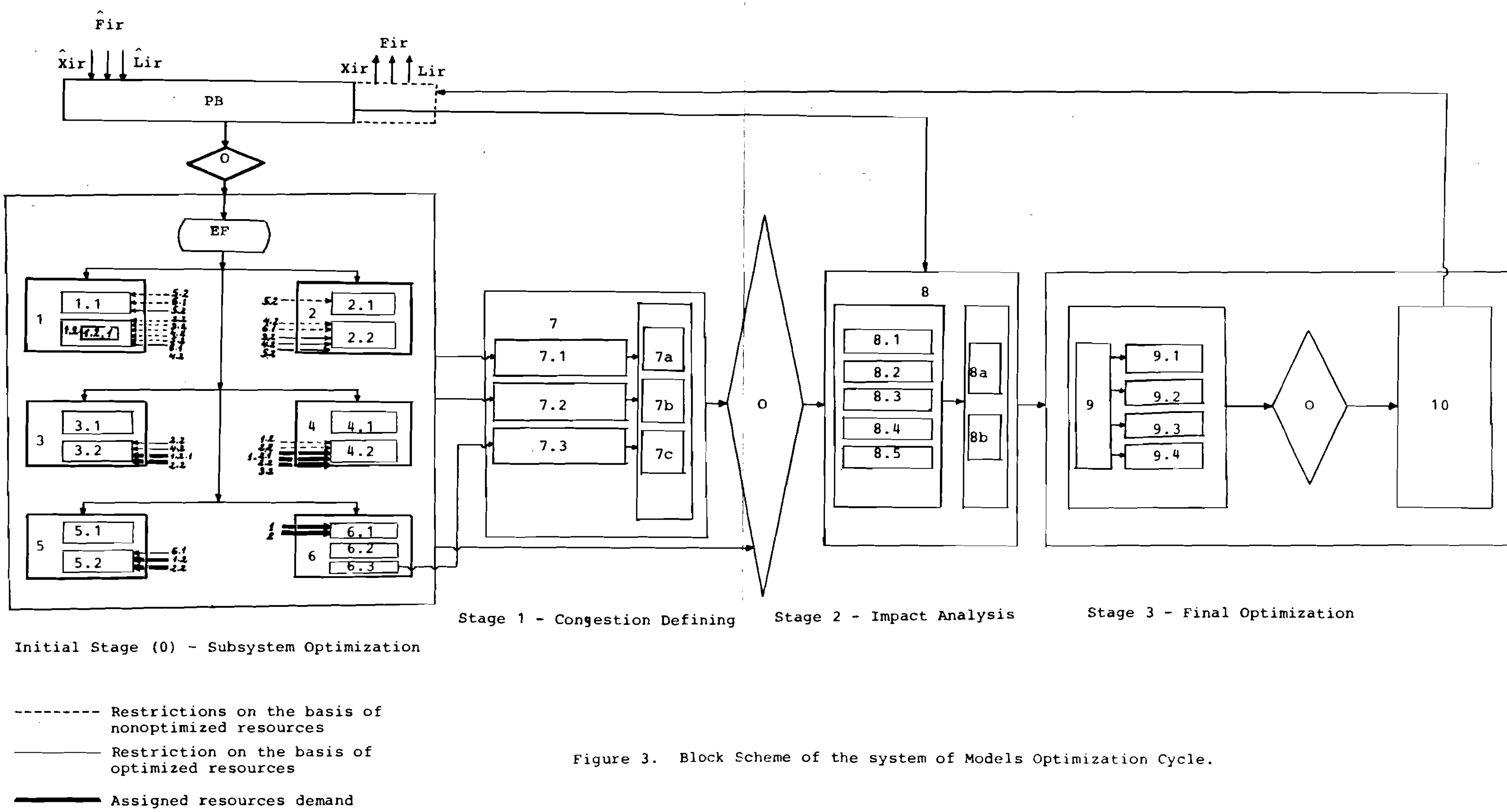

Figure 3. Block Scheme of the system of Models Optimization Cycle.

Notations

PNI - Production of national importance
PLI - Production of local importance
PB - Prospective intraregional input-output balance
O - Operator
EF - Efficiency functions
1 - Agriculture subsystem
1.1 - Optimal territorial distribution of PNI on regional level
1.2 - Technological and territorial optimization of PLI
1.2 - Optimal size of the irrigated land
2 - Industry subsystem
2.1 - Optimal territorial distribution of PNI on regional level
2.2 - Technological and territorial optimization of PLI
3 - Water Resources Subsystem (WRS)
3.1 - Optimal development of WRS on a national level regarding PNI
3.2 - Optimal development of WRS on a regional level regarding PLI
4 - Energy Resources Subsystem (ERS)
4.1 - Optimal development of ERS on a national level regarding PNI
4.2 - Optimal development of ERS on a regional level regarding PLI
5 - Transportation Subsystem (TS)
5.1 - Optimal development of TS on a national level regarding PNI
5.2 - Optimal development TS on a regional level regarding PLI
6 - Migration Subsystem (MS)
6.1 - Needed migration on a regional level regarding PNI and PLI
6.2 - Expected migration on a regional level
6.3 - Difference between the needed and expected migration
7 - Conjestion phenomena
7.1 - Imbalance between the production and resources regarding PNI and PLI
7.2 - Environmental polution defining (on a regional level only)
7.3 - Imbalance between the needed and available labor force
7a - Additional territorial allocation
7b - Additional or less production and resources volume
7c - Additional or less expenditures
8 - Impact analysis
8.1 - Resources impact on the regional development
8.2 - Production volume impact on the regional development
8.3 - Migration impact on the regional development
8.4 - Environmental pollution impact on the regional development
8.5 - Living conditions impact on the regional development
8a - New resources and production needed
8b - Formulation of alternatives for regional development
9 - Strategic type subsystems optimization
9.1 - Environmental protection
9.2 - Migration regulation
9.3 - Health care policy
9.4 - Human settlements policy
10 - Optimization of PLI on a regional level

-- The demand constraints are:

$$\sum_i x_{ilm}(t) \leq b_{lm}(t) \quad . \tag{13}$$

The production volume constraints are:

$$\sum_i a_{im}x_{im}(t) \geq R_i(t) \quad , \tag{14}$$

and zero one constraints are:

$$x_i = \{{1 \atop 0}\} \quad . \tag{15}$$

The remaining constraints for agriculture have to be transformed from the constraints, analogous to the production of national importance (3)-(10) in terms of a special operator.

-- The agriculture production of local importance x_{jr} is to be optimized from technological as well as from territorial aspects within the region:

$$\underbrace{\sum_i \sum_m \sum_n a_{ji}x_{jm}(t)}_{\text{Local resources costs}} + \underbrace{\sum_i \sum_m \sum_n V_{ji}\nu_i x_{jm}(t)}_{\text{Wage costs}}$$

$$+ \underbrace{\sum_i \sum_m \sum_n c_j x_{jm}(t)}_{\text{Intermediate production costs}} + \alpha \underbrace{\sum_i \sum_m \sum_n b_{ji}x_{jm}(t)}_{\text{Reduced capital investments}} \tag{16}$$

$$+ \underbrace{\sum_i \sum_m \sum_l \sum_n (d_{ilm}+\alpha K_{ilm})x_{ilm}(t)}_{\text{Reduced transportation costs}} \rightarrow \min \quad .$$

It is necessary that the intermediate production expenditures be measured in production costs but not in prices when these products can be used for final consumption or export as well.

The connections between the agriculture and the other subsystems within the region might be expressed in the following way:

Limitations according to the resources used by the type:

$$\sum_i \sum_m \sum_n a_{ji} x_{jm}(t) \le \delta A(t) \quad , \tag{17}$$

where:

A = total volume of resources;

δ = coefficient for agriculture density participation in the resources used.

These resources refer to:

- -- land as a natural resource;
- -- subsystem water resources;
- -- subsystem energy resources;
- -- subsystem transportation;
- -- subsystem industry;
- -- subsystem migration processes (in its part of labor resources).

Limitations of total final production volume by the type:

$$p_j x_{jm}(t) \ge Z(t) \quad . \tag{18}$$

Limitations according to the intermediate production when part of this is used for final non-productive consumption:

$$\sum_i \sum_m \sum_n c_j x_{jm}(t) \ge C(t) \quad . \tag{19}$$

The identification of the connections between agriculture and the other subsystems requires that the connectiosn of particular importance be defined. It could be realized in terms of "efficiency function" proposed by M. Albegov [1]. This function shows the influence of the resources volume used on the efficiency of the agriculture (these resources are products of other subsystems of the region or imported from other regions). For our assumptions, the "efficiency function" will appear as follows:

$$\sum_i E_i(A_i, B_i, L_i, M_i) \rightarrow \max \quad , \qquad (20)$$

where

E_i = efficiency function;

A, B, L, M = different resources.

The efficiency function used allows us to connect the agriculture with the other subsystems according to the parameters of great importance only and to neglect those of minor importance. This is of great significance for reducing the number of links between the subsystems. Otherwise the task will be practically unsolvable.

Initial Stage (0) - Description of the Water Resources Development and Links

The water resources from the viewpoint of the production of national importance demand may be treated as a complex national infrastructure system. Its efficiency depends on the existing natural water sources, on the techniques used and on the spatial allocation of the water resources system which is not usually closed within the region boundary. The latter circumstance requires (despite the territorial factor influencing the efficiency of the water system) that regarding the production of a national importance, the territorial efficiency of the water system be defined on a national level, but not on a regional level, as shown for agriculture and industry by formula (12).

The water demand for the production of local importance has to be derived according to the optimal development of the subsystem water users.

At the initial stage this requires:

1. When the agriculture optimizes (the same also goes for industry) the water use has to be estimated in the technological variants as a substitute resource (with regard to fertilizers and other techniques in agriculture and with regard to technologies without need of water in industry). In these cases the water expenditures have to be included in costs but not in water prices. The above requires that the water demand be included in the agriculture model (respectively in the industry model) but not as an independent model. In this way, in the optimization model (16) with regard to water use, the following constraints have to be considered:

   -- for the total irrigated land:

$$\sum_i \sum_m \sum_n U_j^1(t) \leq M^1(t) \quad , \qquad (21)$$

   where:

   U_j^1 = irrigated land for the j-th culture;

   M^1 = total irrigated land;

   -- for water costs:

$$\sum_i \sum_m \sum_j a_{ji} x_{jm}(t) \leq \delta A^1(t) \quad , \qquad (22)$$

   where:

   A^1 = total expenditures for water.

2. Construction of the water resources subsystem for the production of local importance has to be based on the exogenously assigned water demand as a result of the water user subsystem optimization. In this case, the water subsystem optimization has to be made under the same conditions as the productive subsystems according to formula (16). This kind of optimization, does not exclude, and in fact assumes, the existance of variants with common (mutual) use of the water system of national importance.

The connection between water resources with the other subsystems may be expressed on the example of agriculture (it supposes that in terms of the "efficiency function" the significant influence of water on the agriculture efficiency is proven). An iterative feedback has to be treated between the water volume and costs, on the one hand [as a result of formula (16) used for the water subsystem optimization) and the income change in agriculture on the other, in terms of formulae (21) and (22)].

Thus within the limitations for the subsystem water resources (derived in terms of an operator from the limitations (3)-(10), the quantity of water may be determined, when the marginal costs in agriculture become equal to the marginal costs in the water subsystem construction [5].

The subsystem water resources optimization has to use the "efficiency function" in the same manner as the subsystems treated so far.

Initial Stage (0) - Description of the Energy Resources System Development and Links

The problem of energy demand for the production of national and local importance and the construction of the energy resources subsystem is analogous to the water resources subsystem. Here one more feature characteristic exists when the production of local importance is treated. This is the fact that some subsystems (energy users) are at the same time sources of energy materials: animal fertilizers as a source of biogas in agriculture, waste in industry as a source of energy; etc. This requires direct and feedback to be included between the subsystems regarding the use of resources.

Initial Stage (0) - Description of the Transportation Subsystem Development and Links

The transportation is an extremely complex infrastructure system because it has a spatial character and consists of different kinds of transports.

It can be definitely said that regarding the production of national importance $\hat{x}_{jr}$, $\hat{x}^{E}_{jrp}$, and $\hat{x}^{I}_{jpr}$ the transportation demand has to be exogenously assigned to the transportation subsystem as a result of the intersectorial and interregional optimization on a national level. On the other hand, it became obvious that for some sectors the separate region is treated as a point when the territorial optimization has to be made. It was necessary in this case that the production of national importance be optimized regarding their territorial distribution only when the transportation costs were assigned [in formula (12)].

At the same time, it is apparent that a feedback exists between the transportation costs (as a result of the transportation system optimization) and the optimal territorial distribution of the production of national importance. But the territorial character of the production optimization is not a ground for transportation subsystem optimization within the separate region. The reason is due to the transportation operation which is everlasting on the whole territory of the country and as a rule the expenditures made in one region lead to an efficiency in the other regions.

It shows that regarding the production of national importance even the transports which are closed within the region (motor transport; in some cases, river-channel transport; and pipeline) must not be optimized within the region. The reason is that their development has to be defined by their participation as substitute transports in the national model for optimal load distribution among different kinds of transport.

The above statement requires that the transportation system within the region be optimized regarding the production of local importance only (x_{jr}) in terms of the model elaborated [8]:

$$\sum_i \sum_j \sum_k \sum_l \sum_n F_{ijkln}(t) \cdot X_{ijkln}(t) \rightarrow \min \quad , \qquad (23)$$

where

k = type of load;

l = transportation mode;

n = technological mode;

F = reduced annual transportation costs;

X = traffic volume (consisting of loads (X^1) and passenger (X^2) traffic).

This model allows simultaneous optimization of the loads distribution among different transportation modes and the choice of technological measures; the latter are preliminarily optimized according to different traffic volumes.

The model is subject to the total production volume of local importance:

$$\sum_i \sum_k \sum_l \sum_n X_{ijkln} = X_{jr} \quad . \tag{24}$$

The links between the transportation subsystem and the other subsystems are: direct and feedback (production volume and transportation costs).

Initial Stage (0) - Description of the Migration Processes Subsystem and Their Links

The migration on a national level is mainly provoked by the interregional distribution of production (activities). The fact however, that the separate region is usually treated as a point and the production of national importance has to be optimized in territorial aspect within the region, requires that migration be estimated both with regard to the production of national and local importance on the separate region level only.

It is obvious that at the initial stage the labor resources needed within the region have to be defined as a result of the initial state of the separate subsystem, which corresponds to the assigned limitations in formula (9) [7]:

$$\sum_j \sum_m L_{ir}(t) + \sum_{p \neq r} \sum_j L_{ipr}(t) = \sum_j \sum_s V_{qj} X_{jr}(t) + \sum_{p \neq r} \sum_j \sum_s V_{qj} X_{jrp}(t) \quad , \tag{25}$$

$$\sum_j \sum_s V_{qj} X_{jr}(t) + \sum_{p \neq r} \sum_j \sum_s V_{qj} X_{jpr}(t) - \sum_{p \neq r} \sum_j \sum_s V_{qj} X_{jrp}(t) \leq L(t) \quad , \tag{26}$$

where:

s = subsystems in the region.

Here, the labor resources balancing by subregions is made as follows:

$$L_m(t) = K_m(t) - K_m^n(t) \pm M_{pr}(t) \pm CP_{pr}(t) \quad , \tag{27}$$

where:

K = local population

K^n = population of non-working age;

M_{pr} = migration;

CP = commuting patterns.

The local population is derived in terms of the Leslie model [7]:

$$\{\underset{\sim}{K}_m(t)\} = \underset{\sim}{L}_m\{K_m(t_o)\} \quad , \tag{28}$$

where:

$\underset{\sim}{K}_m(t)$ = projected population by subregion m in in time t;

$\underset{\sim}{L}_m$ = Leslie matrix derived by fertility and mortality rates;

$K_m(t_o)$ = column vector of the population in the basic year.

After all subsystems optimization both of a territorial and technological apsect, (shown as symbol *) a new quantity and allocation of the labor resources needed will be derived:

$$\sum_j \sum_s V_{qj} X_{jr}(t) \pm \sum_j \sum_s V_{qj} X^*_{jr}(t) = \Delta \sum_j \sum_s V_{qj} X_{jr}(t) \quad , (29)$$

which will provoke new migration flows needed: $\Delta \sum_j \sum_s M(t)$.

It is very important to underline that the migration processes have a subjective character despite their objective basis. This fact requires that the propensity of the population to migrate should be investigated. This makes it possible to derive the expected migration flows in terms of Rogers' model [9]:

$$\{\underset{\sim}{M}_m(t)\} = \underset{\sim}{G}_m\{K_m(t_o)\} \quad , \tag{30}$$

where:

$\underset{\sim}{M}_m(t)$ = projected population including migration;

$\underset{\sim}{G}$ = multiregional growth matrix

$K_m(t_o)$ = column vector of the population in the basic year.

Here, in the multiregional growth matrix, the migration rates could be derived in terms of La Bella's model [3]:

$$q_m = f(a, \Delta R_m, \Delta C_m, \Delta h^R_m, \Delta h^C_m, r, L_m, \nu_m) \quad , \tag{31}$$

where:

a = coefficient;

ΔR_m, ΔC_m = existing differentiation in the costs and benefits of population living in different subregions;

Δh_m^R, Δh_m^C = expected differentiation in growth rates of the same factors;

L_m = differentiation of the potentiality for finding work;

r = discount factor;

ν = expected costs of the move.

The links between the migration processes and the other subsystems are direct and feedback according to the above described procedures. At this stage, the links express the difference between the needed and expected migration flows within the region, and to and from the other regions.

THE CONGESTION PHENOMENA IN THE REGION

The first stage of the calculation cycle (after the initial stage) has to define the consequences of the concentration of different elements (factors) in a separate subregion (in some cases in a separate point) as a result of the subsystems' optimization and their links formed at the initial stage. The congestion phenomena in a separate subregion (point) is not possible to be considered at the initial stage because of the different sequence of separate subsystems' optimization. In this respect different kinds of congestions will appear as a result of the summarizing of the congesting factors by subregions (points) within the region.

An additional imbalance between the productive resources and the production volume, both for the production of national and local importance by subregions (points) possibly exists:

$$\sum_j \sum_m a_{ij}\hat{X}_{jr}(t) + \sum_j \sum_m a_{ij}X_{jr}(t) = \sum_m A(t) \pm \Delta \sum_m A(t) \quad . (32)$$

A difference between labor resources needed and those available by subregions (points), and respectively, a difference between needed and expected migration flows, will apparently appear as a result of the optimization of subregions and the propensity of the population to migrate (see pp.16-19):

$$\sum_m M^*_{pr}(t) \pm \sum_m M^{exp}_{pr}(t) = \Delta \sum_m M_{pr}(t) \quad . \qquad (33)$$

The environmental pollution problem will apparently arise at this stage and on the subregional (point) level only. This fact must explicitly be considered here because environmental pollution depends on the concentration of different productive and social components in one point (subregion) and it becomes impossible to express this on a national (and respectively, on an interregional) level. The environmental pollution by subregions (points) may be expressed by the formation of a matrix A_Ψ consisting of n vectors $(0,\ldots,0, \Psi_i, 0,\ldots,0)$ for the pollutants of the i-th sector which are detached in producing the unit of product i.

Environmental protection may be expressed by including the additional coefficients a'_{ij} for the expenditures of the i-th sector to purify the unit of product producing by the j-th sector according to the accepted normative.

As a result of the congestion phenomenon the main objective, feasible consequences stemming from this phenomenon have to be formulated for the region. These consequences are closely related to the subject matter on p. 19. Generally speaking, they can induce:

1) the necessity of additional or less resources,

$$\pm \Delta \sum_{i} \sum_{m} a_{ji} x_{jm} \quad ; \tag{34}$$

2) additional or less products for non-productive consumption,

$$\pm \Delta \sum_{m} \alpha_{i} Z_{m} \quad ; \tag{35}$$

3) additional migration inflow or outflow,

$$\Delta \sum_{m} M_{pr} \quad , \qquad \text{or} \qquad \Delta \sum_{m} M_{rp} \quad ; \tag{36}$$

4) additional or less expenditures (social, environment, etc.),

$$\pm \Delta \sum_{i} \sum_{m} C_{j} x_{jm} \quad ; \tag{37}$$

5) additional territorial allocation of production,

$$\Delta \sum_{i} \sum_{m} \sum_{l} E_{ilm} x_{ilm} \quad ; \tag{38}$$

and respectively, additional or less transportation costs,

$$\pm \Delta \sum_{i} \sum_{m} d_{j} x_{jm} \quad . \tag{39}$$

IMPACT OF THE SUBSYSTEMS ON REGIONAL DEVELOPMENT

The second stage of the calculation cycle is based on the previous stages. It allows us to take into account the impact both of the preliminary optimization of the subsystems at the intial stage (0) and the consequences stemming from the congestion phenomena at the first stage.

The impact of the subsystems on the regional development at this stage is possible to be estimated in the shape of direct links between the subsystems output and the consequences of the congestion on the one hand, and an intraregional input-output balance on the other. It can be realized with the help of an operator which has to transform the subsystems output and the consequences of the congestion to the aggregated elements of the regional input-output balance.

For example, the new quantities of intermediate resources as a result of the subsystems optimization have to be summarized by products, by subsystems and by subregions in order to be able to derive the new production volume of the subsystems producing these resources (relevantly aggregated):

$$\pm \left(\Delta \sum_{i} \sum_{m} \sum_{s} a_{ji}\hat{x}_{jm}(t) + \Delta \sum_{i} \sum_{m} \sum_{s} a_{ji}x_{jm}(t)\right) = \pm \left(\Delta\hat{X}_{ir}(t) + \Delta X_{ir}(t)\right) \quad . \tag{40}$$

In other cases (for example, the environmental protection consideration), additional equations must necessarily be included in the regional input-output balance:

$$\hat{X}_{i+n,r}(t) + X_{i+n,r}(t) \quad . \tag{41}$$

On the basis of the links transformed by the operator, an impact model for regional analysis should be implemented at this stage. The main goals of this analysis are:

1) to show the new quantity of the resources and the production (activities) volume as a result of the above mentioned consequences; and
2) new alternative variants for regional development may be formulated.

A tentative analysis can be shown on the example of the influence of the final production changing on the total production volume within the region.

If in matrix form, X is the vector of the total production volume, A is n × n matrix of the input coefficients and Z is the vector of the final production, the input-output impact model will be:

$$X - AX = Z \quad , \tag{42}$$

and in the case when I is an identified matrix, the model will be:

$$(I-A)X = Z \quad . \tag{43}$$

If (I-A) has minus magnitude, the reverse matrix will express the total production volume as a function of the final production:

$$X = (I-A)^{-1} \cdot Z \quad , \tag{44}$$

and if

$$(I-A)^{-1} = U \quad , \tag{45}$$

hence

$$X = U \cdot Z \quad , \tag{46}$$

and the coefficients u_{ij} (i, j = 1,...,n) of matrix U express the full costs requirements of the i-th sector which are needed for the unit of the final production of the j-th sector. This allows us to estimate the influence of each change in the quantities and elements of the final production on the total production volume of each sector within the region.

For the purpose of estimating the influence of the different changes of resources on the total production volume for the sectors in the region, an impact model for energy resources could be implemented here. Undoubtedly, this model of a dynamic input-output character could be used successfully for our purposes with some modification which is easily made. It is obvious that in making impact analysis we have to consider the components of national importance as exogenously assigned.

THE OPTIMIZATION PROBLEM FOR THE REGIONAL SYSTEM OF MODELS

At the third stage of the calculation cycle, the problem of optimization within the region has to be solved. There is no doubt that the optimization within the region has to be connected with the final consumption. The problem is, however, very complicated, because of two important circumstances:

1) the final consumption is consistent both with products for consumption (personal and governmental) and of social (and environmental) facilities and living conditions. It is very difficult for them to be commensurable under a unified criterion;
2) the final consumption encloses products (facilities) of local and national importance within the region and the question is, which part of the final consumption has to be optimized on a regional level.

The above two aspects of the problem might be solved taking into account the opportunities given by the previous stage (impact analysis--see p. 23).

Some of the subsystems in the region have feature characteristics in comparison with the subsystems optimized at the initial (0) stage. These particular subsystems are of universal (global for the region) character: environmental protection, migration processes, health care and human settlements. Impact analysis allows some variants of strategic type for the region be formulated regarding these subsystems' development. Their strategic character is determined by their universal influence on all other subsystem development.

The example of migration processes subsystem shows us that as a result of the congestion phenomena (p. 19) the difference between the needed and expected migration flows $\Delta \sum_m M_{pr}$ in (33) may be transformed in terms of the operator (p. 21) and some alternative variants can be analyzed through the impact model (p. 22).

Thus, the problem of regulation of the migration flows arises [7] which can be solved as follows:

-- the optimal size of migration flows M^*_{pr} must be derived when the marginal additonal value of income (I) as a result of migration is equal to the marginal expenditures (E) provoked by migration:

$$\frac{dI}{dE} = 0 \quad ; \tag{47}$$

-- the expected size of migration flows M^{exp}_{pr} must be reduced to the optimal size M^*_{pr} in terms of the modified version of La Bella's model (31) where an additional value of the migration factors have to be included:

$$K_m(t) \cdot q_m + M^*_{pr} = f(a, \Delta R_m, \ldots, \nu_m, \Delta E_m) \quad , \tag{48}$$

where:

ΔE_m = additional expenditures of different character (wages, for houses, social facilities, etc.) which can provoke propensity of the population to migrate.

-- the value of ΔE_m may be derived in terms of the reverse function solving according to ΔE_m where M^*_{pr} = const.:

$$\Delta E_m = f(M^*_{pr}, a, \Delta R_m, \dots, \nu_m) \quad . \tag{49}$$

Optimizing the remaining subsystems of global character in an appropriate manner, one can see that this kind of model is of a strategic type because it simultaneously affects all the subsystems preliminarily optimized. In this respect the criteria are of a global type for the region due to its wide scope.

At the same time this kind of optimization (which is only possible on a regional level), although based on the consequences stemming from the production (activities) both of national and local importance, expresses the specific coordinative functions of the regional management body according to the existing economic and social management mechanism.

Strategic type model sovling allows that the results be transformed into restrictions through an operator (M^*_{pr} is to be transformed to a labor force limitation and ΔE_m to final consumption). On the basis of these restrictions and on some of the restrictions stemming from the impact analysis, it is possible to make an optimization of the final production of local importance. The model will appear as follows--see (2):

$$x_i(t) + x_i^I(t) = \sum_j a_{ij}x_j(t) + y_i(t) \quad , \tag{50}$$

$$y_i(t) = B_j(t) + \alpha_i Z^P(t) + \alpha_i Z^S(t) + x_i^E(t) \quad , \tag{51}$$

where:

y_i = final production;

B_j = capital investments;

z^p, z^s = production of personal and social consumption;

x_i^I, x_i^E = import and export.

The objective function could be:

$$F = \sum_j Z_j \rightarrow \max \quad . \tag{52}$$

The objective function may be connected with the prices in this stage of optimization only and thus can define the structure of all the sectors within the region, which is not advisable to be used on the separate subsystem level--see (16).

The constraints are analogous to (3)-(10) relatively transformed by the operator and stemming from strategic type model solving and the impact model. In this way, the optimal final production (activities) will define the intermediate production structure on the basis of already optimized subsystems.

For this purpose a dynamic-optimization model was elaborated and tested by I. Zimin and W. Orchard-Hays (and was also programmed by the latter) at IIASA and can be successfully used with relatively little modification according to our requirements. This optimization model expresses the specific and direct control functions of the regional management body regarding the production (activities) of local importance.

The final optimization closes the optimization cycle which is shown in block-scheme (Figure 3) including the links with the national system of models.

GENERAL CONCLUSIONS

The following general conclusions can be drawn from the approach proposed here:

-- the construction of the system of models within the region is conform with the specific opportunities for the modeling of separate subsystems on the national and regional level;

-- the differentiation of production (activities) of such a national and local importance is provoked both by the feature characteristics on national and regional modeling and by the specific functions that regional bodies have regarding the production of national and local importance;

-- the differentiation of the optimization cycle of different stages allows that the problem of the criteria and their compatibility be solved;

-- the subsequent development of the closed optimization cycle shows that the interdependencies do not occur between separate subsystems models only, but mainly occur between different models which express different aspects of the subsystems at different stages;

-- the use of marginal estimates (and correspondingly that of efficiency functions) is of great importance for the defining of the concrete basic relations between subsystems that have to be optimized in order to simplify the system of models;

-- the approach proposed for the construction of the system of models allows that a different extent of production (acitivites) aggregation be implemented depending on the concrete purposes at the different stages of the optimization cycle.

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