POLISH ACADEMY OF SCIENCES
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STRATEGIC REGIONAL POLICY

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PART I

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STRATEGIC REGIONAL POLICY

Paradigms, Methods, Issues and Case Studies

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editors

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PART I

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II. REGIONAL POLICIES IN A SYSTEMS CONTEXT

TOWARDS THE INTEGRATED SOCIO-ECONOMIC AND SPATIAL PLANNING

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1. INTRODUCTION

The purpose of this paper is to present an optimization model of spatial organization. By spatial organisation we understand the mutually interdependent subsystems of urban settlements, transportation roads, and agricultural areas. In geometric terms it is a structure formed by the sets of points, lines, and surfaces.

Characteristic feature of this model is that it optimizes the three subsystems jointly and simultaneously. Until recently economic geographers and spatial economists dealt mostly with the optimization of individual subsystems, assuming that other subsystems are given. Attempts were undertaken to build also combined models embracing the problems of residential and transportation choice (Bayce 1978, Los 1979). This paper refers to the latter approach.

Separate optimization of individual subsystems does not take into account redistributional effects erising in the process of mutual interations. This is in fact a suboptimization. It is only the joint and simultaneous optimization of all subsystems that ensures global optimization of spatial organisation.

2. OPTIMIZATION MODEL

Mathematical description of the model is presented in the Appendix 1. Multiple objective decision methods would be probably the best approach to the solution of our problem. For the moment, however, we will apply a simpler method. Namely, we will evaluate the objectives of individual subsystems and combine them in one objective function.

In order to do so we have to define appropriate concepts. The concept of utility of places (for people, industry, and agriculture) and of accessibility to other places seems to be the most adequate. It is reasonable to assume that the best spatial organisation must maximize the utility of given places and their accessibility to the rest of the spatial system.

Having in mind computational possibilities we do accept other related concepts, namely the concepts of bid rent and of transportation costs. The first one is extended to encompass households, industrial enterprises, and farms. By the bid rent of a household we understand the willingess to pay for an apartment in a given city. The bid rent of an industrial enterprise means the willingess to pay for the establishment of one additional place of work in a given city. In the bid rent of a farm, its willigness to pay for the use of one hectare of land in a given area is expressed[1]. Net bid rents were used in computations. The bid rents representing the utility of places are then reduced by transportation costs, being the inverse of accessibility. Spatial organisation is optimal if it maximizes the differences between bid rents and transportation costs.

In the bid rents of households, industrial enterprises, and farms, mutual interdependences between the three subsystems are represented. Thus, the bid rent of a household depends on the job opportunities (industry), and prices of food (agriculture) in the given area; the bid rent of and industrial enterprise - on the resources of labor, the demand of urban population, the supply of agricultural raw materials, the demand of farms; the bid rent of a farm - on the supply and demand of industry, and the demand of urban population.

All three bid rents are assumed constant in the computations. However, their amounts reflect the interdependences mentioned above. Besides, the bid rents of households and industry are sensitive to the economies of scale. The degree of sensitivity of industry is relatively higher.

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[1] The profit yield from 10^3 kgs of agricultural products was used in computations.

The relations between bid rents affect the structure of system which is being shaped by the mechanism of self-organisation.

The volume of flows of population and agricultural products results from their optimal shifts between cities or subregions. In the case of industry we optimize the shift of work places. Industrial commodity flows are then determined in a different way, namely using a gravity type model.

The unit costs of transportation are assumed constant, but their amounts are differentiated and related to the volume of traffic on individual roads. The lowest cost is atached to the roads with moderate intensity of traffic. The traffic on the roads with the heaviest flows is charged with the highest cost (congestion). The cost of traffic on the secondary roads is placed between these two exteremes (slack capacities).

The productivity of agriculture depends on natural conditions, the demand of urban population, and the level of industrialization (raw materials for food processing industry, production means for agriculture). Dependence on urban population and industry assumes the form of a function. It forces the agricultural subsystem to follow the trend of population and industrial subsystems. The influence of natural conditions is introduced as a constraint, as an upper limit of productivity reflecting barriers imposed by soil and climate.

In addition to the interaction of the three subsystems, the functioning and development of system is influenced by the environment. We distinguish two kinds of environment; natural and social. The influence of natural environment is reflected by additional cost borne by industry and urban population (the cost of reduction of population, relatively higher cost of recreation etc.). Social environment exerts its influence in the form of governmental regulations. In our model municipal government imposes taxes on inhabitants and industry. The taxes increase with the size of cities.

Our system is open. Its functioning and development is affected also by outer world. The outer world is assumed uniform and characterized by the introduction of additional rows and columns into the model.

The model satisfies the requirement of self-organisation principle, i.e. that the subsystems be interdependent. As already mentioned the interdependence is implied in the relations between bid rents. It occurs also in constraints imposed on the objective function. They state (condition 2) that the number of work places is equal or less than the number of active population, and (condition 7) that the supply of individual cities with agricultural products depends on population and industry of the cities. The transportation results from optimal commuting, and the optimal flows of industrial and agricultural products.

The objective function combining the effectiveness of three different subsystems is open to discussion. One can raise an objection, whether this form of objective function is admissible. The author was aware of its drawbacks. Nonetheless, I decided to apply it, having in mind that: a) it enables considerable economies in computations: thanks to it, the model remains linear; where occurence of nonlinearities was obvious nonlinear functions were linearized using piece-wise linear functions, b) some essential drawbacks can be removed by the appropriate statement of constraints.

The previous applications of the concept of bid rent allow me to hold the belief that its extension on housing, industrial work places, and agricultural land can be accepted. In this way we solve the problem of valuation of behavior of different subsystems. Notwithstanding, it is thinkable that in the case of great differences in bid rents, the actions of some subsystems will be not payable and, therefore, eliminated in order to ensure global maximum of the objective function, for the function assumes the hard and fast play of economic forces. This attribute of the function, however, can be kept in reasonable limits. For this purpose we impose the following constraints:

1. The number of work places cannot fall down below a determined minimum. Thus, the model ensures a determined level of employment (condition 3).

2. The growth of industry has its upper limit which can be related to the resources of labor and capital (condition 4).

3. The city sizes have both lower and upper limits related to housing stock. The stock is equal to or greater than the number of households (condition 8 and 9).

4. The maximal and minimal share of active population commuting to other cities and from other cities to the given city is determined. Thus, the model prevents both the undesired drainage and invasion of individual cities (conditions 10 and 11). In large cities there is higher inflow than outflow of commuters. In small cities - vice versa.

5. Agricultural productivity is limited from below, so that extremely productive areas cannot ruin less productive areas. The upper limit reflects the existence of natural and socio-economic barriers (conditions 5 and 6).

In the form of these constraints, the basic interests of population, industry, and agriculture have been ensured. We left, however, a broad margin for the spatial shifts of socio-economic activities. Within these limits we allow economic forces for hard and fast play in order to improve the effectiveness of system.

3. THE RESULTS OF OPTIMIZATION

As the result of optimization we obtain two kinds of data:

1) The state of spatial organisation after optimization. These will be figures representing the location of population and economy in cities, the productivity of individual agricultural areas, and the flows in individual directions. No constraints are imposed on actual distribution of population. The figures represent a state which is admissible and desirable on the ground of accepted objective.

2) The optimal distribution of employees, assuming that they do not change their places of residence. We impose a constraint that the number of active population in individual cities be constant. This condition causes that the results of optimization concerning other subsystems are different than in the first case.

The model was tested under various assumptions concerning spatial preferences of population, industrial enterprises, and farms reflected in their bid rents. After initial experiments, two sets of assumptions were accepted. The first set assume that the system is dominated by concentration processes. Primary city is most attractive, and the attractiveness decreases as the city sizes decrease. This does not apply to small cities located in the vicinity of primary city, on which high value is set. The second set assumes moderate concentration. Medium - size cities are more prefered then the primary city. The small cities in the vicinity of primary city are valued but in losser degree than in the first case. In both variants, agriculture is highly productive. Considerable part of its production can be exported to other regions.

The model includes 507 variables ($13^2 \times 3$), and 170 constraints [2].

The results obtained meet our expectations. The optimization implemented under the first set of assumptions (concentration variant, Figs. 5-9), result in the following spatial shifts in comparison to initial state.

1. Urban population and industry increased in three largest cities. The increase is observed also in these small cities located in the vicinity of primary city which have favorable conditions for further growth. Such conditions do not occur in city 11, which is already industrialized and suffers from polluted environment. Other small cities, as well as medium-size cities show the decrease of population and industry.

2. Primary city is both the destination as well as the source of commuting. The size and dispersion of commuting is rather low, which suggest that the distribution of residential areas and work place coincide to high degree.

3. The productivity of agriculture increased in all subregions. Due to high demand of agricultural products, it reached the upper limits. The highest level of production occurs in subregions with

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[2] Algorithm, programs, and computations have been carried out by Jan Dawidowski, Center for Data Processing, Poznań Academy of Economics.

the largest cities and partly around the primary city.

4. Industrial commodity flows increased on the main roads, following the trends of industrial production and urban population. The agricultural products show two transport orientations; a) local flows within individual subregions, b) export from external zone to other regions. Such a pattern of flows reveals the influence of distance and transportation cost.

These spatial patterns and shifts resulting from the optimization show that the model is sensitive to the main defining parameters, namely to the bid rents. The sensitivity to transportation cost turned out much weaker. As far as commuting is concerned only in the case of city 3 and 4, high transportation costs reduced the utility of places to such extent that the active population resigned from commuting and migrated to other cities. Industry and agriculture reacted to transportation cost in the way mentioned above. The constraints imposed by natural and social environment, according to our expectations, reduced urban population and industry in city 11. In the case of other cities these constraints, together with transportation cost, diminished the values resulting from bid rents. The outside world, defined by accepted assumptions, proved less attractive for urban population and industry than the region considered. This resulted in the shift of population and employees to the region. On the other hand, less productive agriculture in the outside world forced it to import agricultural products from the region.

The optimization carried out under the second set of assumptions (moderate concentration variant) yielded also expected results. Urban population and industry shifted to medium - size cities, The last one lost a small part of its population and somewhat greater part of its industry. This trends of urban population and industry was followed by commuting and industrial commodity flows. Agriculture changed in the same way as in previous variant, and so did the relations with outside world.

In the above two experiments we did not impose constraints on the distribution of active population and allowed population of individual cities to change in accordance with its spatial preferences. Now, we change the approach. Namely, we assume that populations of individual cities ramain constant, and under this assumption we optimize the spatial organisation of the rest of system.

The results thus obtained are in one respect rather surprising. One could expect that the stability of urban population will give rise to more intensive commuting. Nothing of the sort happend. This suggests that commuting, after it reaches certain level, cease to be sensitive to further stimuli. Substantial differences occured, instead, in the spatial distribution of industry. Neither primary city nor medium-size cities increased to the upper limits. Stable working population did not allow industrial centers to reach the most effective sizes. Confronted with this barrier, industry relocated partly to other regions. This result is opposite to that obtained in previous experiments.

The optimization model is in its present form a static one. However, we can repeat this optimization procedure, assuming new spatial preferences revealed in a previous step. In this way time factor can be introduced and continuous changes can be optimized. A proper dynamic model must include also discrete changes. Therefore, further extension of the model is necessary.

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Appendix 1

Optimization model

Notations:

a_j^* - optimal productivity of agriculture in a subregion j,

c_{ij} - unit transportation cost on a line ij,

d_{ij} - distance between cities ij,

d_{ij}^L - distance between subregions ij,

u_{ij} - bid rent of an apartment in a city i that a head of household working in a city j is willing to pay; net bid rent, i.e. bid rent minus actual rent, was used in computations,

v_{ij} - external economies obtained by enterprises as the result of a shift of one workplace from a city j to a city i: they are expressed in bid rents that the enterprises are willing to pay for such a shift,

w_{ij} - profit from 1 ton of agricultural goods produced in a subregion j and sold in a subregion i; another way of expressing preferences can be a net bid rent (bid rent minus production costs) that farmers from a subregion i are willing to pay for the use of 1 hectare of land in a subregion j,

A_{ij} - amount of agricultural goods produced in a subregion j and sold in a city i,

A_{kj} - amount of agricultural goods imported to city k, depending on its population and employment,

B_j, B_o - upper and lower limits of agricultural productivity; the production cannot be continued beyond these limits,

N_j - number of workplaces in a city j in the initial state,

E_{ij} - number of workplaces shifted from a city j to a city i in optimization procedure,

E_{kj} - number of workplaces in a city k, occupied by employees living in a city j,

E_j^* - number of workplaces in a city j after the shifts resulting from optimization procedure,

G_{ij} - interactions between industries located in cities i and j (industrial commodity flows calculated by means of a gravity equation),

H_i - maximal size of city i determined by its housing stock,

H_{oi} - minimal size of city i determined by the assured number of workplaces,

I_k, J_k - coefficient determining the dependence of amount of agriculture products imported to a city k on population and employment of this city,

K_j - ability of enterprises to create new workplaces in a city j,

L_j - area of agricultural land in a subregion j,

M_i - minimal number of workplaces in a city i (social constraint),

N_i, N_{oi}' - maximal and minimal percentage of active population of a city i working in other cities,

N_j, N_{oj} - maximal and minimal percentage of employees of a city j commuting from other cities,

P_i, P_j - active population in cities i and j,

P_{ij} - active population living in a city i and working in a city j,

P_{ik} - active population commuting to a city k from cities i,

P_{kj} - active population of a city k moved from a city j,

P - total number of population in the region,

P_i^*, P_j^* - active population in cities i and j after the shifts resulting from optimization procedure,

Q_i - costs of the protection of environment borne by industry of a city i,

R_i - costs borne by population of a city i due to the pollution of environment,

S_i - charges imposed on the population of a city i by the social environment (social institutions),

T_{Py}^* - industrial commodity flows on a road y resulting from the spatial distribution of industry after optimization,

T^*_{Ay} - agricultural commodity flows on a road y resulting from the spatial pattern of agriculture after optimization,

Z_i - charges imposed on the industry of a city i by the social environment (social institution).

Objective function:

$$\mathrm{Max} = \sum_j \Big[\sum_i P_{ij}/u_{ij} - P_i - S_i - c_{ij} \cdot d_{ij} \Big) + \sum_i E_{ij}(v_{ij} - Q_i - Z_i - E_j) d_{ij}^2 +$$

$$+ \sum_i A_{ij}(w_{ij} - c_{ij} \cdot d_{ij}^L)\Big]$$

subject to:

$$\sum_i E_{ij} = E_j \tag{1}$$

$$\sum_j E_{kj} \leqslant \sum_i P_{ik} \tag{2}$$

$$\sum_j E_{ij} \geqslant M_i \tag{3}$$

$$\sum_j E_{ij} < K_i \tag{4}$$

$$\sum_i A_{ij} \geqslant B_o L_j \tag{5}$$

$$\sum_i A_{ij} < B_j L_j \tag{6}$$

$$\sum_j A_{kj} < \sum_j (I_k P_{kj} + J_k E_{kj}) \tag{7}$$

$$\sum_j P_{ij} < H_i \tag{8}$$

$$\sum_j P_{ij} \geqslant H_{oi} \tag{9}$$

$$\sum_{j=i}' P_{ij} < N_i P_i \tag{10}$$

$$\sum_{i \neq j} P_{ij} \leqslant N_j P_j \tag{11}$$

$$\sum_{j \neq i} P_{ij} \geqslant N_{oi} P_i \tag{12}$$

$$\sum_{i \neq j} P_{ij} \geqslant N_{oj} P_j \tag{13}$$

$$\sum_i \sum_j P_{ij} = P \tag{14}$$

or

$$\sum_j P_{ij} = P_i \tag{15}$$

$$P_{ij} \geqslant 0 \tag{16}$$

$$E_{ij} \geqslant 0 \tag{17}$$

$$A_{ij} \geqslant 0 \tag{18}$$

Solution:

$$P_i^* = \sum_j P_{ij} \tag{19}$$

$$P_j^* = \sum_i P_{ij} \tag{20}$$

$$E_j^* = \sum_i E_{ij} \tag{21}$$

$$a_j^* = \sum_i A_{ij}/L_j \tag{22}$$

$$T_{Py}^* = \sum_{ij,y} P_{ij} \tag{23}$$

$\sum_{ij,y}$ - sum over all persons commuting in directions ij using a road y,

$$T_{Ey}^* = \sum_{ij,y} G_{ij} \tag{24}$$

$\sum_{ij,y}$ - sum over all industrial products transported in directions ij using a road y,

$$T^*_{Ay} = \sum_{ij,y} A_{ij} \tag{25}$$

$\sum_{ij,y}$ - sum over all agricultural products transposted in directions ij using a road y.

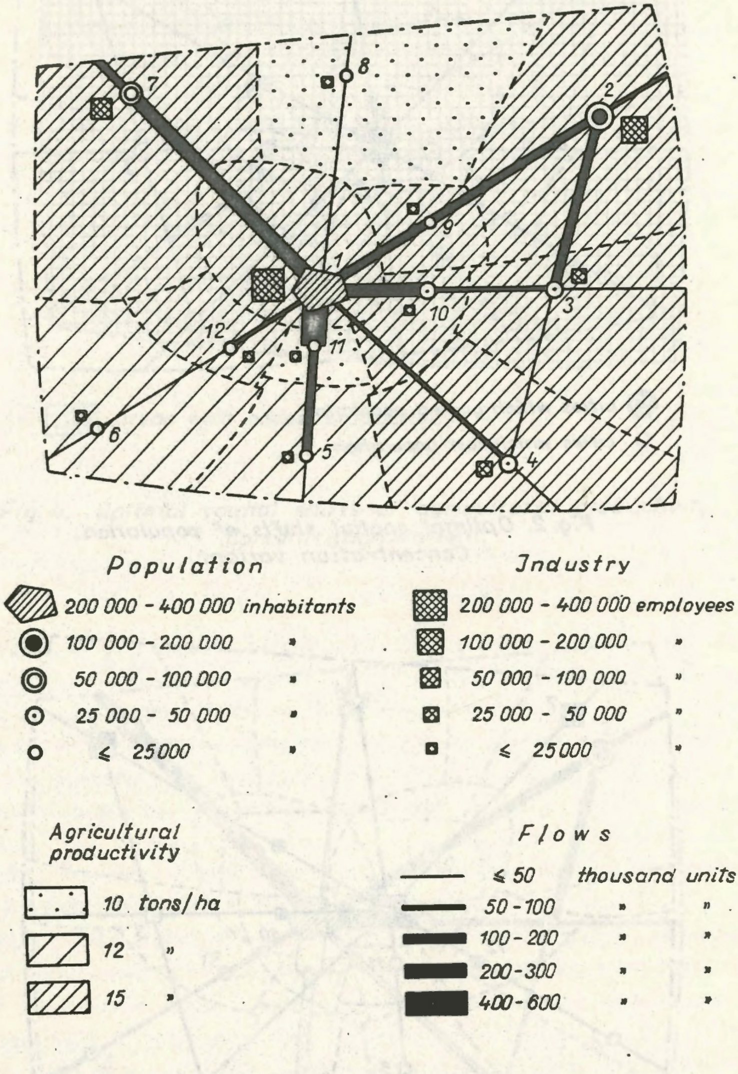

Fig. 1. . Optimal spatial organisation. Concentration variant.

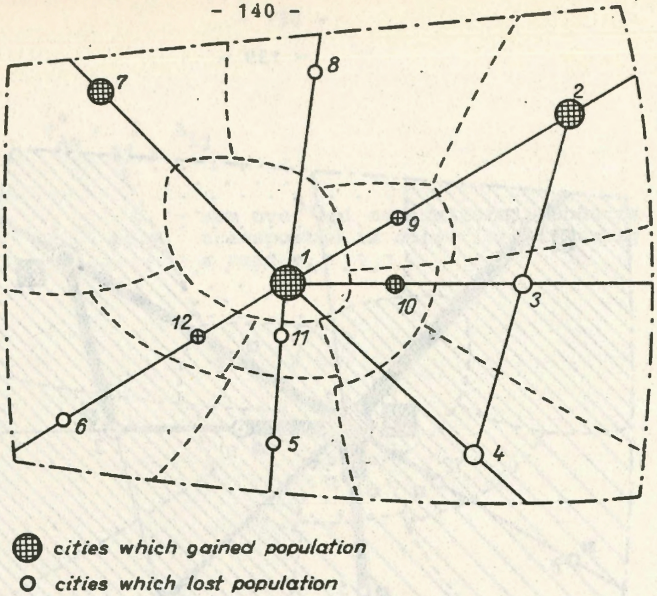

Fig. 2. Optimal spatial shifts of population. Concentration variant

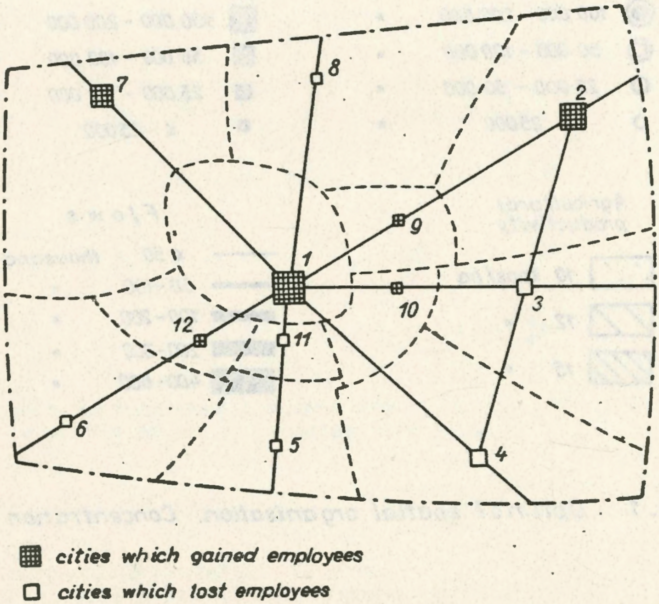

Fig. 3. Optimal spatial shifts of industry. Concentration variant

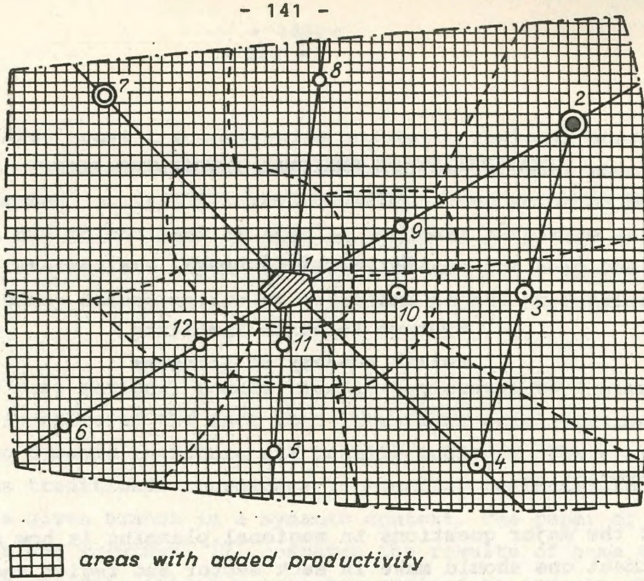

Fig. 4. Optimal spatial shifts of agricultural productivity. Concentration variant.

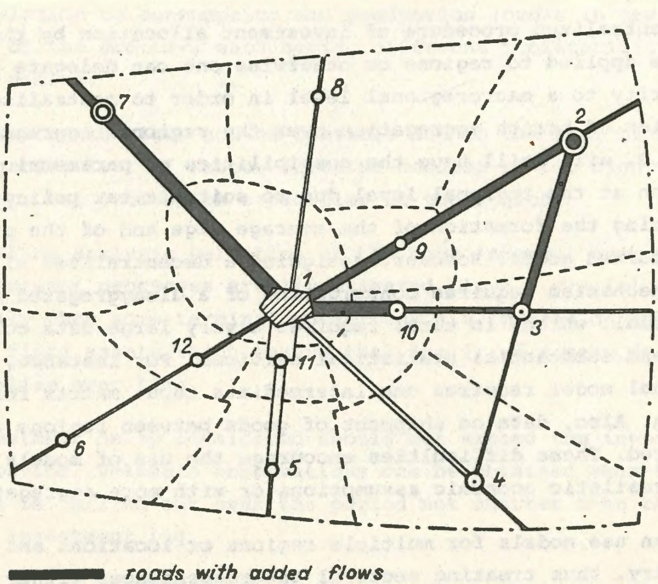

Fig. 5. Optimal spatial shifts of transportation. Concentration variant

DISCUSSIONS

Paper by A. Straszak

Discussion participants: K. Polenske, S. Ikeda, R. Espejo, A. Straszak.

Main point of discussion was the question of influence exerted by introduction of new technologies ("intelligent production systems emerging from combination of robotics, automation, artificial intelligence and specialized computer applications") on the society in general and on the labour force and its structure in particular. Notwithstanding some analyses which suggest that the net result would be decrease of the higher skill jobs' share, it was indicated that obvious historical trends still point towards more of intellectual work and less of the physical one in the future. This was also the main factor behind the move towards the "information society", as witrassed in the Japanese national/regional plans and schemes, where it is combined with a broader quality-of-life view of regional problems.

Paper by L. Lacko

Discussion participants: R. Bolton, K. Polenske, L. Lacko.

Two questions were taken up, mainly for clarification: the contents of "background activities", which are those not needing big factories or sophisticated equipment and therefore only small input capital, and the notion of responsibility, which refers to local organizations, able to carry greater responsibility, having at their disposal greater financial resources.

Paper by G. Gavrilov and O. Panov

Discussion participants: K. Polenske, R. Espejo, R. Bolton, L. Lacko, S. Ikeda, G. Gavrilov.

The first question touched concerned the notion of "private strategy" used in the paper. This notion refers to these strategies (substrategies) which are worked out by and for the individual organisms and which could only afterwards be integrated into an overall strategy. Such strategies were said to be the leading ones on the present stage of development in Bulgaria.

Another question concerned participation of local bodies in the planning process. Thus, it turned out that local authorities are interacting in Bulgaria with the central, national level ones through the strategically-oriented dialoque with sectoral organisms, mainly ministries. Formal planning is more concentrated on elaboration of one-year and 5-year plans.

A clarification point was also raised connected with the environmental issues and resources accounted for. Thus, it was stated that over a given territory all strategically important resources are taken into consideration.

The last question concerned similarities and dissimilarities between Hungary and Bulgaria and was answered by L. Lacko. Thus, among similarities in planning for regional dimensions were quoted: care for infrastructure, environment, and recreation and tourism facilities. Dissimilarities were said to mainly reside in planning and management system. For Hungary the double approach of socio-economic and physical planning was quoted.

Paper by R. Domański

Discussion participants: L. Kajriukstis, U. Loeser, R. Domański.

Two questions were addressed: first, how can such activities as recreation or forestry be incorporated into the model, and second, whether this model can be applied to developing countries, mainly in the Third World, where large urban inmigrations are often occurring. The first question was answered by stating that currently the model recognizes such spatial entities as points, lines and circles, and whichever activity can in its spatial aspect be expressed in their terms, can be incorporated in the model. As far as application of the model in developing countries is concerned, it was deemed possible to formulate appropriate mathematical structures in which problems of creation of verylarge urban centers and local agricultural decline could be accomodated, quite satisfactorily.

Paper by K. Cichocki

Discussion participants: S. Dresch, K. Cichocki.

Discussion cetered around the role of consumption in models considered, insofar as consumption is related to the main object of these models, namely investments. It has turned out that in several runs of the models consumption was used as an element of the vector objective function. A variant envisaged takes monotonic growth of consumption as reference to objective function, with the monotonic growth based both upon official statements and on the estimates provided by analyses made by other research centers in Poland.

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