Regional Model of Employment and Environment

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Abstract

The paper deals with multicriterial decision - making methods and models of regional planning. To this aim multicriteria decision model which integrates aspects of natural environment and economy, as well as, labour market of Szczecin Province (Poland) is presented.

This model incorporates three submodels:

- economic submodel
- submodel of labour market
- submodel of environment.

These submodels can be formally treated as linear, static and multicriteria model form. Criteria describe gross national product (GNP) in region, unemployment in region and degradation of natural environment (the last two criteria are minimised).To get efficient model solutions, the interactive method - DIDAS-L has been chosen.

The developed model comprises 23 decision variables and 23 constraints. The decision variables include: output of production and services in region, employment and its changes and investments.

Efficient solutions forecasting possible scenarios of economy, charges and fines for degradation of environment. Results of the model has been implemented in Szczecin Region.

Key words: regional planing, multi-criteria models

Introduction

The development of different techniques for the multi-criterion modelling and optimisation, shows that presently in the decision making problems in regional systems, when conflicting objectives are involved, the methods of interactive programming are most frequently used. Generally, mathematical models have linearly static or dynamic

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character. The models include, fully or at least to necessary extent, three basic groups of criteria: economic, demographic and social, and the natural environment.

In paper we attempt to construct a model for the economy of a voivodeship (province), treated as a region. In the process of construction of the model, an adaptation of the models formulated by *Nijkamp et al. (1990), Krawiec, Markiewska (1995) and Fischer et al. (1996)* has been carried out. In order to optimise the model, the DIDAS-L method developed by *Rogowski, Sobczyk and Wierzbicki (1988)* has been employed.

1. A model of regional economy and environment

A regional model, which is now being constructed, is a spatial model that integrates aspects of the natural environment of economy as well as the labour market. It takes into account an interaction between a region and the central level of administration. Since the model is to map a real, particularly complex, system in which economic, environmental and employment subsystems can be distinguished, the main model will incorporate the following three submodels:

- **economic submodel**. This is a model that describes economic links between the regional and the national economies, and also the economic links between various activities within the region are accounted for. The submodel describes main activities associated with the production and services in the region.

- **labour market submodel**. It describes the employment (supply and demand for labour force) in the region in integrated sectors of economy. The demand for the labour force is linked to the structure of production. The supply of labour force is determined by demographic factors.

- **environment submodel**. It deals with the emission of pollutants associated with different economic activities, and the investments aimed at the improvement in the quality of the natural environment.

Economic submodel

In this submodel the following modules are included:
(I) production output,
(II) final demand,
(III) production capacity.

(I) Production output module

The production output in a region is described by a system of balance equations and technological constraints in r=1, 2, ..., R sectors of production and services. These equations can be written in the form:

$$A_r x_r - f_w \geq f_z \qquad (0.1)$$

where:
A_r - matrix of technical coefficients,
$x_r = [x_1 \ldots x_R]$ - vector of output in sectors,
$f_w = [f_{1w} \ldots f_{rw}]$ - vector of internal demand in the region,
$f_z = [f_{1z} \ldots f_{Rz}]$ - vector of external demand.

(II) Final demand module

The final demand module incorporates:
- consumption in households,
- investments of private and state-owned companies,
- investments financed by the state budget,
- exports beyond the region.

(III) Production capacity module

Key variables in this module are the production potential of the region and the degree to which this potential is utilised. The production potential of the region is described by the vector of state $a = [a_1 \ldots a_R]$ in matrix A_r in the module (I). The most important included components are an investment rate and employment in enterprises and sectors of non-material production and services.

Labour (employment) submodel

In this submodel the demand for the labour force in the scale of the whole region and in specific sectors is analysed. The demand for the labour force is related to the system of production by means of the balance:

$$l_R = \gamma_R^T \cdot x_r \leq l_{sR} \tag{0.2}$$

where:
l_R - total demand for the labour force for all sectors in the region,
γ_R - vector of coefficients of the labour force demand in specific sectors,
x_R - vector of sectors,
l_{sR} - vector of upper limits of employment in the region.

A linear relation between the production volume of a sector and the labour force demand enables an easy input of results obtained in the economic submodel, which regard changes in productivity, utilisation of productive potential, and pay policy.

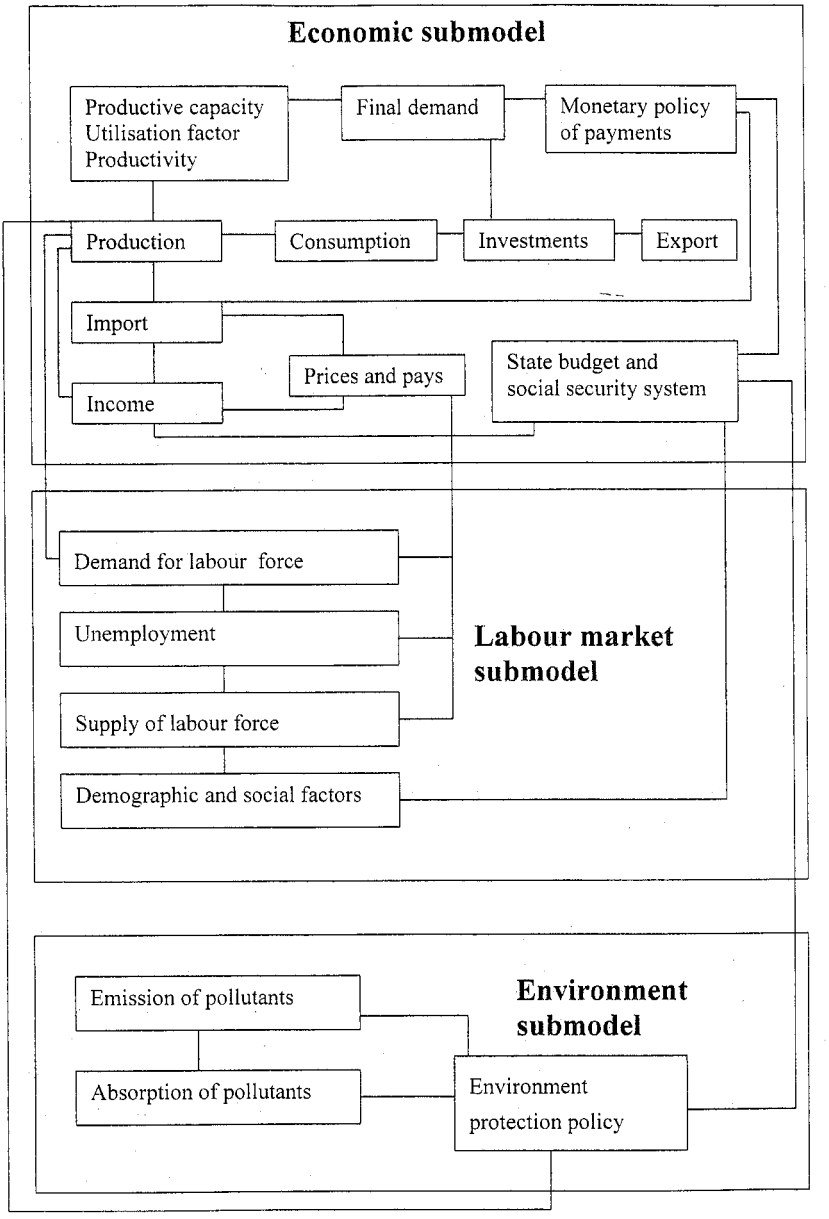
Environment submodel

The following factors affecting the quality of natural environment are included:

1. Emission of air pollutants caused by:
   a) combustion of mineral fuels,
   b) production processes.
2. Disposal of industrial and communal sewages to ground waters.
3. Water intake for production purposes of industry and agriculture sectors.
4. Waste dumping.

The model of regional economy is illustrated in Fig. 1.

Fig. 1. The structure of the regional economy model.



The submodels which have been discussed above can be formally treated as a linear, static and deterministic, multi-criterion model in the form:

$$Z(x) = [Z_1(x),...,Z_k(x)] \rightarrow \max \quad (0.3)$$

$$Ax \leq b \quad (0.4)$$

$$x \geq 0 \quad (0.5)$$

where:
Z(x) - k-dimensional vector of criteria,
A - matrix of technical coefficients of combined submodels,
b - vector of problem constraints,
$x = [x_1,...,x_R, x_{R+1},...,x_{R+p}]$ - vector of decision variables.

The decision variables include: output of production and services in the region, employment and its changes, and investments.

The decision variables describe various domains of activities. Activities associated with the industrial production belong to the production domain, divided into the production sectors. It has been assumed that each sector manufactures only one product (individual or aggregate).

Criteria

$Z_1(x) \rightarrow \max$ - gross national product (GNP) in the region,
$Z_2(x) \rightarrow \min$ - unemployment in the region,
$Z_3(x) \rightarrow \min$ - degradation of the natural environment.

As it can be seen, the above criteria, concerning different domains of the regional economy, are not coherent, and are in conflict to one another. For instance, if we maximise the GNP in an industrial region, then the emission of pollutants will increase. If we minimise the unemployment, then the GNP in the region may decrease. And, finally, if we minimise the emission of pollutants, then the decline in the GNP and the growth in unemployment may occur. Therefore, some efficient solutions, which will satisfy decision makers in the region, and in the same time will meet all criteria under consideration, have to be found.

2. The regional employment model

The current economic situation in Poland is characterised by a relatively high unemployment rate in comparison to the countries of the European Union, which prompts an urgent need of starting the research aimed at modelling the regional labour markets and environment protection.

As a real object of modelling, the economy and employment in Szczecin voivodeship has been assumed.

Basing on the data from the Regional Statistical Office, upper limits of investments in the most important branches of economy, i.e. in the industry and engineering, agriculture and forestry, and in other branches of economy and the environment protection, were estimated. In addition, two activities associated with the employment, namely the investments effecting the employment restructuring and the institution of public works, were incorporated in the model.

All the above types of investments influence directly the increase in employment. The rates of employment growth per one-billion-zloty annual investments were estimated for various branches. It follows from the data analysed so far that the most effective investments proved to be those associated with the employment restructuring (training, professional requalifying, information systems on available jobs, credits, professional development), and also the investments in industry and agriculture. On the other hand, the least effective in creating new jobs were the investments in the environmental protection sector.

Relating the economic and service activities and investments to the decision variables regarding the region's population resources, supply of workers, demand for labour, and the number of unemployed, allowed to estimate the rates of demographic transformations and the growth of new jobs, and also enabled to determine the standards for the labour demand. These made it possible to generate the matrix A of technical and economic coefficients of the model.

The activities incorporated in the model are integrated and they include:

- industry - x_1,
- building industry - x_2,
- agriculture - x_3,
- forestry - x_4,

- transportation - x_5,
- telecommunications - x_6,
- trade -x_7,
- other branches of material production - x_8,
- municipal management - x_9,
- housing management and non-material services - x_{10},
- science and education - x_{11},
- health service and social security - x_{12},
- other sectors and branches of the national economy - x_{13},
- region's population - x_{14},
- demand for labour in the region - x_{15},
- supply of workers - x_{16},
- total unemployment - x_{17},
- investments in the industry and engineering - x_{18},
- investments in the agriculture and forestry - x_{19},
- investments in other sectors and branches of economy - x_{20},
- investments in the environmental protection - x_{21},
- expenditures on the employment restructuring - x_{22},
- public works - x_{23}.

The decision variables: x_1 - x_{13} describe the employment in the region, variables x_{14}, x_{16} and x_{17} describe the labour market, and variables x_{18} - x_{23} denote investments and expenditures which create new jobs. The model constraints take into account basic demographic information on the region's population, employment in specific branches of economy, and the volume of investments in the region.

The criterion functions describe:

1. Gross national product (GNP) generated in the branches and sectors of the region - this functions are subject to maximisation. GNP is a sum of gross added values generated by activities incorporated in the model. The gross added value was calculated on the basis of data included in the "Statistical Year-Book" (1994) as a difference between the total value of products and services, and the value of indirect consumption.
2. Total unemployment in the region - this function is subject to minimisation.
3. Degradation of the natural environment - this function was minimised, and expresses charges and fines for the air pollution, disposal of sewages, water uptake, and dumping of wastes.

The developed model comprises 23 decision variables and 23 constraints. It has been based on the statistical data from the years 1994-1996, and to high degree takes into account the theoretical assumptions specified in section 1. The model is optimised by making use the DIDAS-L algorithm.

Examples of efficient solutions, concerning the main activities in Szczecin voivodeship, has been listed in table 1. They should be regarded as an illustration of chosen information opportunities offered by the model, and the efficiency of applied optimisation algorithm, as well as the method of its application.

Solution 1 was obtained by applying the initial model of the regional economy, and corresponds to the economic conditions of the year 1997. It presents the economic capacity of the region on the assumption of the possibly full utilisation of the population's potential and real expenditures on investments.

Solution 2 was obtained on the assumption of partly changed constraints, namely the investment expenditures were increased: in the industry and building sector by 290 billion zloties, i.e. by 11%, in the agriculture and forestry by 100 billion zl, i.e. by 33%, in other branches of economy by 500 billion zl, i.e. by 11%, and on the environment protection by 40 billion zl, i.e. by about 9%. Altogether, the expenditures were increased by 930 billion zloties. This gave rise to the growth in GNP by 1307 billion zl and the decrease in the number of unemployed by 4,600, compared to solution 1.

In solution 3, we did not take the values of ideal criteria as the reference point, as it was the case in solution 2, but decided to worsen the value of the last criteria, i.e. those describing the charges and fines for the environment degradation. On such an assumption, in solution 3 a further growth in GNP by 121 billion zloties and a decrease in the unemployed people by 1,100 occurred, but at the cost of the degradation of the natural environment (increase of charges by 60 billion zl), all in comparison with solution 2.

Of course, the model can also be used for other simulations, enabling thus forecasting of possible scenarios of the economy and employment development in the region.

Table 1 - Solution alternatives of the regional employment model

Lp.	Activities	Efficient solution		
		1	2	3
	Employment (in thousands):			
1.	in industry	84,7	97,9	99,0
2.	building industry	32,0	32,0	22,0
3.	agriculture	61,0	50,0	50,0
4.	forestry	3,3	3,3	3,3
5.	transportation	31,0	31,0	31,0
6.	telecommunications	6,0	6,0	6,0
7.	trade	52,	52,0	52,0
8.	other branches of material production	2,0	2,0	2,0
9.	municipal management	16,	16,0	16,0
10.	housing management and non-material services	4,1	4,1	4,1
11.	science and education	31,0	31,0	31,0
12.	health service and social security	23,0	23,0	23,0
13.	other sectors and branches of the national economy	30,0	30,0	30,0
14.	Region's population (in thous.)	983,0	983,0	983,0
15.	Demand for labour in the region (in thous.)	397,1	401,7	402,8
16.	Supply of workers (in thous.)	491,5	491,5	491,5
17.	Total unemployment (in thous.)	94,4	89,8	88,7
	Investments (in billion zl)			
18.	in the industry and engineering	1710,0	2000,0	2000,0
19.	in the agriculture and forestry	200,0	300,0	300,0
20.	in other sectors and branches of economy	4500,0	5000,0	5000,0
21.	on the environmental protection	460,0	500,0	500,0
22.	on the employment restructuring	50,0	50,0	50,0
23.	Public works (employment in thous.	5,0	5,0	5,0
	Criterion functions:			
1.	GNP (in million zl)	30339,8	31646,5	31767,1
2.	Number of unemployed (in thous.)	94,4	89,8	88,7
3.	Charges and fines for the environment degradation (in million zl)	317,6	230,4	290,5
	Ideal values (q^{id}) of criteria or the reference point - solution 3			
1.	GNP (in million zl)	30937,5	31880,5	31880,5
2.	Number of unemployed (in thous.)	89,1	87,7	87,7
3.	Charges and fines for the environment degradation (in million zl)	0,0	0,0	200,0

4. Conclusions

The paper presents the first stage of building a model and system supporting economic decisions and natural environment protection at regional level in Poland.

The model includes three the most important domains of regional policy: economy, labour market and environment protection.

For describing real systems as economy or environment protection, a linear, multicriterial model was used and for its optimisation - an interactive technique of multicriterial programming - DIDAS-L.

The model and the used method of optimisation let simulate behaving of the real systems which are economy and environment protection in region according to a change of constraints and the reference point in the criteria space.

The main task is restructuring regional labour markets in connection with economy and environment protection.

The empirical model of labour market was built on data from the chosen region of Poland (Szczecin Voivodeship). Then it was optimised and some interesting practical results were obtained. These results can be used by the State authorities or regional self - governements for supporting decisions in the domain of regional employment policy and environment protection.

At the moment efforts to build a dynamic model describing economy and environment protection in region are occuring. This model will be a component of an informatic system supporting economic - social decisions at regional level in Poland.

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