POLISH ACADEMY OF SCIENCES
SYSTEMS RESEARCH INSTITUTE

STRATEGIC REGIONAL POLICY

A. STRASZAK AND J.W. OWSIŃSKI
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PART II

WARSAW 1985

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STRATEGIC REGIONAL POLICY

Paradigms, Methods, Issues and Case Studies

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editors

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PART II

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VI. METHODS:

MONITORING, MODELLING, CONTROL

STRATEGIC REGIONAL DEVELOPMENT POLICY MAKING USING A FUZZY MODEL

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Abstract. Determination of regional development strategies is considered. The regional system is viewed as a multiproduct company operating in a competitive environment. A best development strategy is sought to yield a best effectiveness and stability, and a flexible response to changes in environment. To account for an inherent "softness" of the problem, a fuzzy model is developed. The model is simple and computationally tractable.

1. Introduction

Strategic regional development is one of most relevant yet difficult issues to cope with by regional authorities. The difficulty stems mainly from: growing structural changes in technological, socioeconomic, environmental, etc. factors, increasing dynamics and instability (uneveness) of economic growth of different branches, considerable uncertainty and risk as to all critical factors and aspects, unreliability of forecasts, etc. In fact, all these difficulties are a result of a competitive (economically and politically) environment which is rapidly changing. To these changes the regional system should be capable to respond in a flexible and well-timed way.

The above difficulties clearly suggest that a (computerized) support, based on some formal models, would greatly help regional authorities make strategic decisions.

Modeling of regional strategies should evidently proceed due to an integrated approach (see, e.g., Straszak and Wagle, 1977; Kochetkov, 1984) to jointly account for the main components, such as marketing, investment, production, technological, social, ecological, and organizational (sub)strategies, all in an integrated sectoral-spatial dimension. The integrated approach implies some issues to be solved. First, certain characteristic proportions between the mentioned strategic components should be maintained to achieve a stable rate of development. Second, a balance between the long /medium/ short - term dimensions should be obtained. In practice, it means that for short-term development some market mechanism, and for long-term development some planned mechanisms should be included. Third, since there are many different strategic aspects and variables, some quantitative trade-offs should be developed. Evidently, by necessity, they should not pretend to be precise for long-term cases, but should rather be viewed as some guidelines. There are also many other important issues and implications of an integrated approach to strategic regional development which are, however, beyond the scope of this paper; details may be found, e.g., in Kochetkov (1984).

In the paper we propose a model for analyzing and designing strategic regional development policies. From the previous brief summary of basic issues and difficulties to be accounted for, we can clearly see that most, if not all, of the mentioned elements to be reflected in a model are inherently ill-defined, human-perception-related, imprecise, vague, etc. - in another words, "soft".

Fuzzy sets theory may provide effective formal tools for dealing with "soft" problems. We will propose here a fuzzy model. The model is a derivation and extension of a family of fuzzy decision models for regional development policy making proposed in a Kacprzyk and Straszak (1979, 1980a, 1980b, 1981, 1982, 1984) which proved to be quite successful.

Following the line of reasoning of Kacprzyk and Straszak (1979, 1980a, 1980b, 1981, 1982, 1984), we consider the problem in a multistage decision making setting. The region is considered to be a multi-product line company (a set of companies) which is formally represented as a system under control. Its state variables are the "product line" activities where products are, first, some specific production activities in which the region is specialized. Second, there are also some more general "products" as, e.g.; R&D (research and development), "knowledge", investment, infrastructure, and cultural level. Only a balanced evolution of all of them, following some preference pattern (playing the role of some aspiration levels), can guarantee an adequate strategic development. As input (control) to the regional system, a strategy option at the particular control stage is taken. A function between a strategy option and the resulting product line activities is assumed known.

As an external variable, a forecast of structural environmental changes and competition is assumed.

Assessment of a given strategy (strategy options at the consecutive development stages) proceeds by a "cost/benefit" analysis with "costs" related to the satisfaction of constraints on the consecutive strategy options chosen, and "benefits" related to the attainment of a prefered product line activities. Both the "pointwise" (at a particular development stage) and temporally distributed aspects of assessment are accounted for.

A best development strategy is sought which yield the highest assessment of the mentioned type. Basically, we attempt to find a "safety-first" strategy.

Our model makes an extensive use of experts' testimonies which may be provided as approximate, linguistic data. Moreover, it is analytically and computationally simple.

It may be a valuable tool to yield guidelines as to regional development strategies which can provide much insight into the essence of the problem, and then serve as a basis for more complex and detailed models.

Our notation will be standard. $A \subseteq X$ is a fuzzy set in X and $\mu_A : X \to [0,1]$ is A's membership function. We will informally equate, and interchangably use, A and $\mu_A(x)$. For basic properties, operations, etc. on fuzzy sets, see, e.g., Bellman and Zadeh (1970) or Kacprzyk (1983).

2. A model of strategic regional development policies

Analysis and design of strategic regional development policies is here dealt with in terms of multistage decision making scheme (Bellman and Zadeh, 1970 ; Kacprzyk, 1983). Its essence is sketched in Fig.1 to be meant as follows. A development strategy A has N components, $a_0, \ldots, a_{N-1}$, to be called policies, corresponding to the consecutive development stages $t=0,1,\ldots,N-1$.

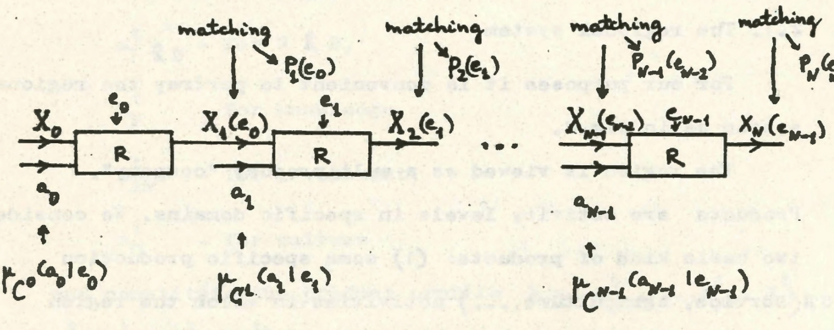

Fig.1

At t=0 the regional system R is characterized by some product profile X_0, and under a policy a_0 and environment status e_0 proceeds to a new product profile $X_1(e_0)$; under a_1 and e_1 proceeds to $X_1(e_1)$, etc. A policy a_t is subjected to a fuzzy constraint $\mu_{C^t}(a_t \mid e_t)$ and a product profile $X_{t+1}(e_t)$ is subjected to matching with a preferred product profile $P_{t+1}(e_t)$. Environmental status influences the fuzzy constraint, regional system dynamics, and the preferred product profile. The problem is to find an (sub) optimal strategy yielding mainly a best compromise between the "costs" (satisfaction of the fuzzy constraints) and "benefits" (matching of the preferred product profiles), and considering some additional aspects to be discussed later.

For clarity, in the sequel we will not explicity indicate that $\mu_{C^t}(a_t \mid e_t)$, $X_{t+1}(e_t)$ and $P_{t+1}(e_t)$ are functions of e_t, and write $\mu_{C^t}(a_t)$, X_{t+1} and P_{t+1}, respectively.

Let us now consider in more detail the regional system and its dynamics, and the strategy assessment ("cost"/"benefit" relation).

2.1. The regional system

For our purposes it is convenient to portray the regional system as in Fig.2.

The region is viewed as a multiproduct "company". Products are activity levels in specific domains. We consider two basic kind of products: (1) some specific production (service, agriculture,...) activities in which the region specializes, and (2) some general "products" (R&D, knowledge, investment, infrastructure, culture, etc.) which are in fact prerequisites for development. Evidently, we can choose the products according to a particular situation.

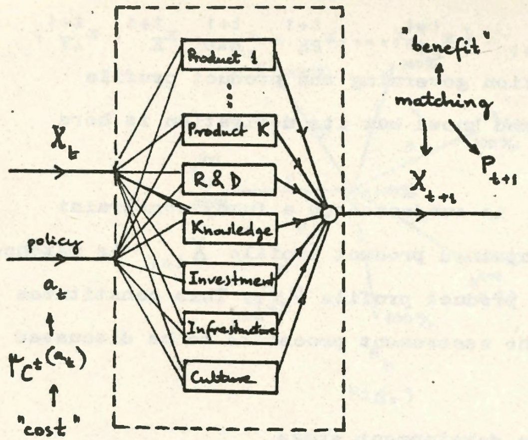

Fig.2

The activity levels at stage t in the particular products are denoted by:

x^t_{p1} - for product 1,

....

x^t_{pK} - for product K,

$x^t_{R\&D}$ - for R & D,

x^t_K - for knowledge,

x^t_{iV} - for investment,

x^t_C - for culture

and constitute the product profile $X_t = (x^t_{p1}, \dots, x^t_{pK}, x^t_{R\&D}, x^t_K, x^i_{IV}, x^t_{IA}, x^t_C)$.

At stage t, a policy a_t is applied, and from a present product profile X_t the regional system proceeds to a next product profile $X_{t+1} = (x_{p1}^{t+1}, \ldots, x_{PK}^{t+1}, x_{R\&D}^{t+1}, x_{K}^{t+1}, x_{IV}^{t+1}, x_{IF}^{t+1}, x_{C}^{t+1})$. A relation governing the product profile transitions is assumed known but its derivation is here beyond the scope.

The policy a_t is subjected to a fuzzy constraint $\mu_{C^t}(a_t)$ and the obtained product profile X_{t+1} is matched against a preferred product profile P_{t+1}. This constitutes two components of the assessment procedure to be discussed below.

2.2. Assessment of a development stage

Assesment of a development stage t is basically performed by relating "costs", i.e. how well a constraint on the policy is satisfied, and "benefits", i.e. how well a preferred product pattern is matched. This is what might be called effectiveness; another aspect of assessment is stability which has to do with how evenly the product profiles evolve. This is related to the whole trajectory and will be discussed in Section 2.3.

As to the "costs", the policy a_t is subjected to a fuzzy constraint $C^t \subsetneq A_t$ defined as a fuzzy set in the space of possible (or relevant) policies at stage t. The grade of membership $\mu_{C^t}(a_t) \in [0,1]$ indicated how good (preferable) policy a_t is at stage t.

As to the "benefits",, we first should define the product profile X_{t+1}. It is convenient to portray it as shown in Fig.3. For each product activity, say x_{PK}^{t+1}, its obtained value is expressed in percentages.

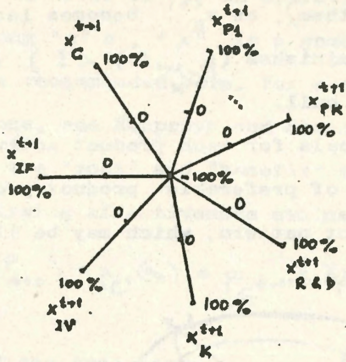

Fig. 3

The value 100% means that this is a perfect result which can guarantee coping with any technological change, competition, etc. The value 0% means basically that the result obtained makes "survival" possible but in a somewhat favourable competitive environment. The value -100% means that the "product" is lagging, and will certainly imply the loosing of competitiveness, so that first some competitiveness is to be restored.

The preferred product pattern X_{t+1} is represented similarly as the product profile P_{t+1}. However, for each product activity, say x_K^{t+1}, we define a fuzzy subgoal as shown in Fig. 4. It means that the obtained values of x_K^{t+1}

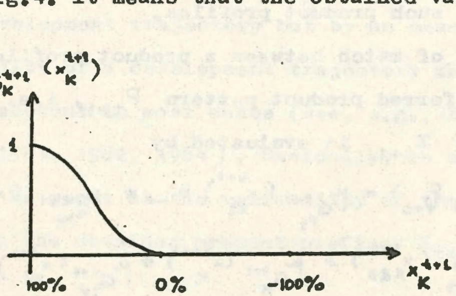

Fig. 4

close to 100% are the most desirable (preferable) ones ($\mu_{G_K^{t+1}}(\cdot) = 1$ for them); as x_K^{t+1} becomes less than 100% its desirability diminishes ($\mu_{G_K^{t+1}}(\cdot) < 1$), and below 0% its desirability is null.

The fuzzy subgoals for each product activity as given above form a "ring" of preferable product profiles, i.e. the preferred product pattern, which may be illustratively represented as in Fig.5.

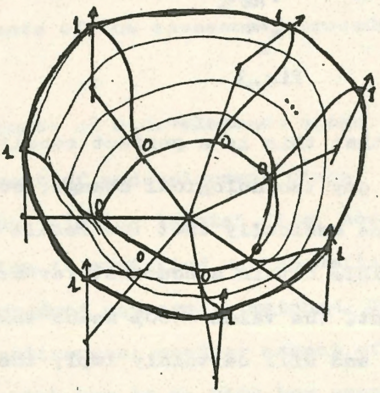

Fig.5

The desirable (preferable) product profiles should be within the above "ring", and desirable are those policies which result in such product profiles.

The degree of match between a product profile X_{t+1} and its related preferred product pattern P_{t+1}, i.e. the goodness of the obtained X_{t+1}, is evaluated by

$$\mu_{G^{t+1}}(X_{t+1}, P_{t+1}) = \mu_{G_{P1}^{t+1}}(x_{P1}^{t+1}) * \ldots * \mu_{G_{PK}^{t+1}}(x_{PK}^{t+1}) * \\ * \mu_{G_{R\&D}^{t+1}}(x_{R\&D}^{t+1}) * \mu_{G_K^{t+1}}(x_K^{t+1}) * \mu_{G_{IV}^{t+1}}(x_{IV}^{t+1}) * \\ * \mu_{G_{IF}^{t+1}}(x_{IF}^{t+1}) * \mu_{G_C^{t+1}}(x_C^{t+1}) \qquad (1)$$

where " $*$ ", here and later on, is an operation $[0,1]*[0,1]\to[0,1]$, e.g., a t-norm. Among " $*$ "'s , " $\wedge$ " is a good, safety-first choice, and may be recommended here. For a discussion of this and other operations, see Kacprzyk and Straszak (1982, 1984).

By combining the "cost" and "benefit" evaluation we arrive at the following effectiveness evaluation of stage t

$$\mu_{E^{t+1}}(a_t, X_{t+1}, P_{t+1}) = \mu_{C^t}(a_t) * \mu_{G^{t+1}}(X_{t+1}, P_{t+1}) \tag{2}$$

2.3. Assessment of the trajectory

The development trajectory is basically a sequence of the consecutive development stages t = 0,1,...,N-1, with their "costs" and "benefits".

The effectiveness of the development trajectory is evaluated by

$$\mu_E(a_0,\dots,a_{N-1} \mid X_1,\dots,X_N; P_1,\dots,P_N) = \mu_{E^1}(a_0, X_1, P_1) * $$
$$* \mu_{E^2}(a_1, X_2, P_2) * \dots * \mu_{E^N}(a_{N-1}, X_N, P_N) \tag{3}$$

and, once again, " $\wedge$ " is a safety-first choice.
We can also introduce importances of the particular development stages as in Kacprzyk and Straszak (1984).

The effectiveness is certainly an extremely important aspect of a development trajectory but by no means the only one. The stability of a development trajectory should also be taken into account in most cases (see, e.g., Kacprzyk and Straszak, 1981, 1982, 1984). Basically, in our context stability will be meant as the variability of the matching degrees between the obtained product profile X_{t+1} and

preferred product pattern P_{t+1}.
For simplicity, this variability may well be related to two neighboring development stages, t and t+1 (Kacprzyk and Straszak, 1981, 1982, 1984), and the degree of variability at stage t+1 is

$$\mu_{V^{t+1}} = v(|\mu_{G^t}(X_t, P_t) - \mu_{G^{t+1}}(X_{t+1}, P_{t+1})|) \tag{4}$$

where $v: [0,1] \longrightarrow [0,1]$ is such that:

(a) $v(.) = 1 \qquad \text{if } \mu_{G^t}(.,.) = \mu_{G^{t+1}}(.,.)$

(b) $v(.) = 0 \qquad \text{if } |\mu_{G^t}(.,.) - \mu_{G^{t+1}}(.,.)| = 1$

(c) $\tau_1 > \tau_2 \Rightarrow v(\tau_1) > v(\tau_2)$

The stability of the trajectory is

$$\mu_V(a_0, \ldots, a_{N-1} \mid X_1, \ldots, X_N ; P_1, \ldots, P_N) = \mu_{V^1} * \ldots * \mu_{V^N} \tag{5}$$

The evaluation, i.e. effectiveness and stability, of the whole trajectory is therefore

$$\mu_{EV}(a_0, \ldots, a_{N-1} \mid X_1, \ldots, X_N ; P_1, \ldots, P_N) = \mu_E(a_0, \ldots, a_{N-1} \mid X_1, \ldots, X_N ; P_1, \ldots, P_N) * \mu_V(a_0, \ldots, a_{N-1} \mid X_1, \ldots, X_N ; P_1, \ldots, P_N) \tag{6}$$

i.e. constitutes a compromise between effectiveness and stability; "$\wedge$" is here also a safety-first choice.

2.4. Designing a regional development strategy

In the previous sections we derived an evaluation of the development trajectory, i.e. a measure for analysing a regional development strategy.

The next step is to design (determine) a regional development strategy. In this case we seek an (sub)optimal strategy $A^* = (a_0^*, \ldots, a_{N-1}^*)$, such that

$$\mu_{EV}(a_0^*, \ldots, a_{N-1}^* \mid \cdot, \cdot) =$$
$$= \max_{a_0, \ldots, a_{N-1}} \mu_{EV}(a_0, \ldots, a_{N-1} \mid \cdot, \cdot) \qquad (7)$$

i.e. which yields a best compromise between effectiveness and stability. Evidently in practice the above maximization may proceed at most over some strategy scenarios whose set is relatively small.

In designing a strategy we can sometimes also with to change the preferred product patterns P_{t+1}'s which play the role of aspiration levels.

3. Concluding remarks

In the paper we proposed a relatively simple model for designing regional development strategies. We viewed the regional system as a multi-product company and look for a strategy that could make it possible for the region to best cope with a changing and competitive environment. We sought in fact wide-product and safety-first strategies. To account for an inherited "softness" of the problem, we used some fuzzy decision making approach which closely paralleled the basic line of reasoning applied in our previous works on regional development policies (Kacprzyk and Straszak, 1979, 1980a, 1980b, 1981, 1982, 1984)

In the model we can use approximate (say, linguistic) values of entities and relations. This is extremely important in case of a long-term strategic analysis when precision is an unnatural requirement. Those approximate values lead to approximate results which are however often what is really needed: to get insight into the issues involved, and obtain some guidelines as to the basic dependences, all that quickly and easily, even at the expense of "accuracy". The model is certainly worth a further, more detailed study.

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DISCUSSIONS

Paper by I. Masser

Discussion participants: R. Espejo, A. Straszak, I. Masser.

Discussion focussed on functions which should be performed by local government and on proper balancing of these functions. This regards e.g. the strategic monitoring function and the eveluation and appreciation functions. A lack of such a balance may lead to impairment of planning and implementation capacities in local governments. It turns out crucial to set up a mechanism for getting a feedback, through reporting, hearings - seemingly - redundant information, related to own plans and acttions. Modern computing equipment may greatly help in carrying out this task, but it must be used in a very delicate manner.

Paper by D. Boekemann and R. Kulikowski

Discussion participants: I. Masser, S. Dresch, S. Ikeda, R. Kulikowski, D. Boekemann.

The discussion concentrated first of all on the institutional side of the systems modell, with particular attention paid to the differences between Austria and Poland in that domain. The authors acknowledged existence of such differences, but pointted out that they can be reduced to the question of proportions, since e.g. there is in Poland an important, although not very large, share of market-oriented tourism operations. When the international tourism market is considered, differences get even smaller. In case of Poland the main problem is adequate cooperation between various operators in the tourism and recreation field*, be it specialized enterprises, trade unions, institutions owning facilities for their employees etc. This applies as well, to investment policies and regional promotion, made on the basis of investments and other approaches.

Utility functions of local authority decisions were said to be assessed primarily on the basis of monetary value of decisions made.

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* Most of these operators enlarge recently the market-oriented share of their activities (eds.).

Paper by M. Steiner and U. Posch

Discussion participants: A. Mouwen, S. Ikeda, M. Steiner.

First, in answering the question on possibilities of a foreasting use of the results obtained it was indicated that factor analysis by itself does not reveal the causal structure, which would be necessary for any sort of forecasting application. Thus, only a comparative study could be undertaken. On the other hand, the available time series of the data did not go beyond the period 1971--1981, and for some items only 1971-1979, and therefore the comparative study could not encompass the dynamics of processes in question, but only the static aspects.

Paper by J. Kacprzyk and A. Straszak

Discussion participants: R. Espejo, I. Masser, J. Kacprzyk.

Discussion centered around the need of implementing computer-based information systems using approaches which would not lose much of the information available and still present it in a simple and legible way. Besides the fuzzy-set-theoretic constructs other approaches were cited, such as Bayesian inference rules. Within this context the questions related to extensions of such applications were raised, pertaining namely to knowledge-based expert systems. These systems,nowadays in the development stage, may contain information in terms of "if... then..." statements, where both conditions and events are fuzzy defined. When developed and tested, such systems may have a great impact on observation and analysis of socio--economic processes.

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