ECONOMICS & Sociology

Małgorzata Sej-Kolasa, Taxonomic Methods in Environmental Management, *Economics & Sociology*, Vol. 2, No 2, 2009, pp. 114-122.

Małgorzata Sej-Kolasa
University of Economics in Wroclaw, Poland
malgorzata.sej-kolasa@ue.wroc.pl

TAXONOMIC METHODS IN ENVIRONMENTAL MANAGEMENT

Received: July, 2009
1st Revision: September, 2009
Accepted: October, 2009

ABSTRACT. Precise and easily available information is the essential tool in environmental management. The society-economy-environment system is described by many diagnostic characteristics. The aim of this paper is to draw the attention to the special usefulness of taxonomic methods, which allow the classification and organisation of multivariate objects in the feature space.

JEL Classification: Q56, Q57 ***Keywords***: taxonomic methods, linear ordering, environmental management.

Introduction

The increase of material prosperity of societies is accompanied by the rise of danger to human health, the conditions of ecosystems and natural resources. The evaluation of the effectiveness of all actions leading to the improvement of the condition of the natural environment requires comprehensive and credible information about the state of the natural environment, as well as the conditions and tendencies that shape it. The policy-makers, at various levels, and politicians are equally responsible for the intertwining problems such as unemployment, health care, as well as the condition of the environment.

Environmental protection is an interdisciplinary problem. Many branches of science, which use various study methods, deal with the study of the surrounding reality. The socio-economic system forms a self-contained whole with the natural environment. The elements of the society-economy-environment system influence one another and are mutually dependant.

One of the more crucial symptoms of the complexity of economic-ecological phenomena is the necessity to use a large number of diagnostic characteristics to describe them.

It is hard to find a definition of the term *complex phenomenon* in specialist literature. Kukuła describes the *complex phenomenon* as an abstract construct depicting the qualitative state of directly immeasurable real objects, described by a number (more than one) of diagnostic variables [6].

The diagnostic characteristics which describe the studied problem change under the influence of various factors, including the ones of random character, and moreover they remain in interrelationships. Considering the above, we can discuss the multidimensionality of the society-economy-environment system.

Taxonomic methods seem to be extremely useful for the spatial studies concerning the environment and its protection. Taxonomy is a multivariate branch of comparative analysis, which deals with the rules and methods of comparison, i.e., the ordering and classification of multivariate objects in feature space.

The aim of this paper is to present a synthetic description of taxonomic methods, as well as to point out the usefulness of these methods in environmental management.

The term *taxonomy* comes from two Greek words: *taksis* – arrangement, order and *nomos* – law, and denotes the study of the rules of ordering and classification. For a long time, ordering and classification constituted one of the basic elements of collecting knowledge about the human world. The first attempts at ordering, of a highly taxonomical character, appeared in biology, and it was on the basis of biology that the first basic postulates concerning taxonomy were formulated. According to Sokal and Sneath the postulates can de described as [2]:

1. the best taxonomy is the one in which the singled-out class contains the highest number of information and is based on the possibly highest number of characteristics;
2. every characteristic has an equal *a priori* importance while creating a natural class;
3. the general similarity of objects in a set is the function of similarity according to all the characteristics included;
4. a separate class can be formed on the basis of a dissimilar character of the relationships between objects from different classes;
5. the similarity between objects is studied disregarding the historical change of the objects.

Taxonomy was perceived as a crucial form of research activity. Jevons formulated several logical postulates, which should be considered during the classification procedure [5] (compare also [2]):

1. classification is the elementary premise of all deliberations which are the foundation of knowledge;
2. the isolated groups should allow for the making of inductive generalisations;
3. every classification should be made according to unambiguous criteria;
4. the most valuable generalisation is the one which is in conformity with the natural system (which suits the biggest number of goals);
5. every classification is connected to the observation field, which means that there are many classification systems of the studied phenomenon.

Taxonomic methods – basic information

Taxonomic methods found application in spatial, comparative socio-economic research. The modelling of socio-economic phenomena, with the use of taxonomic methods, may be a step on the way to their explanation, prediction and control.

The basic issues which should be taken into account during the complex analysis of ecological objects[1] include the quality of environment, the degree to which the rules of sustainable development have been implemented and the quality of life. In any of these fields, economic-ecological phenomena of different qualitative value, constituting separate criteria for comparison of ecological objects, can be distinguished.

Due to the aim of this study, the taxonomic methods can be divided as follows [7] [4]:

1. Methods of ordering objects:
   a) linear organisation – the projection of multivariate space onto a straight line; it allows the establishment of the hierarchy of objects, that is the ordering from the

[1] for the purpose of this study the term ecological object will cover all objects undergoing taxonomic study and being a part of the society-economy-ecology system.

object which is highest in the particular hierarchy to the object which is lowest in the hierarchy,

b) non-linear organisation – the projection of multivariate space onto a plain; it does not allow for the establishment of hierarchy of objects but only the establishment of similar objects to each given object.

2. Methods of grouping of the studied objects:
   a) direct grouping methods – provide the groups of objects without moving them between groups in the subsequent stages of their grouping,
   b) group iterative methods – the initial division into groups of objects, the choice of the function criterion of *goodness* of the grouping, the choice of the rules for the moving objects between groups which allows the increasing *goodness* of the grouping, the establishment of the rule which ends iteration.
3. The methods of choosing the representatives of objects and diagnostic variables:
   a) methods based on the matrix of the distance between the compared objects,
   b) methods based on the matrix of coefficients of correlations between potential diagnostic characteristics.
4. The aggregate methods (synthetic) of the construction of diagnostic variables:
   a) standard methods, which require the defining of the standard of development and are based on the determination of the distance between the objects studied and the standard,
   b) standardless methods, which do not require the defining of development standard.

The research which uses taxonomic methods proceeds in the following stages:

1. The formulation of the aim of the analysis (preliminary research hypotheses).
2. The establishment of the factual, territorial and temporal scope of research, in particular the specification of the elements of the set of objects and the set of initial features.
3. The compilation of complete, up-to-date, essential and credible statistical data[2]:
   – establishing the sources of data and acquisition of source data,
   – making the data mutually comparable,
   – the elimination of observations with extreme values,
   – the interpolation of missing information,
4. Statistical analysis of initial data:
   – the definition and analysis of descriptive parameters (average values, dispersion values, asymmetry values and concentration values),
   – the evaluation of the degree and direction of the correlation between initial variables.
5. The choice of the optimal subset of the diagnostic variables:
   – the elimination of quasi-constant variables,
   – the elimination of correlated variables,
   – the establishment of the final list of variables.
6. The ordering and classification of objects in the feature space:
   – the choice of classification algorithms,
   – the establishment of distance metrics,
   – the establishment of the method of normalisation and aggregation of variables,
   – making calculations.
7. The analysis and interpretation of the results, the formulation of final conclusions.

The procedure of a taxonomic study requires, mainly, the establishment of the subject and space of ordering and/or the classification and the detailed description of the aim of study.

[2] For the measurement of quantity and quality of statistical information see: [8].

The subject and space of a taxonomic study

The basic category in taxonomic analysis is the concept of object. In research on environment, the type of objects analysed will depend on the level of environment protection management. In Poland, environmental management is carried out on three administrative levels: national government, voivodship administration and local administration (district and municipal). The three levels correspond with the three sets of objects: country (in the case of international comparisons), voivodships, districts and municipalities.

The environment protection management occurs not only on the level of the objects resulting from the administrative division of the country. The subject of study can include different groups of objects, e.g., companies or protected areas.

All the processes that take place in the environment, as well as in the whole economy, happen within a period of time. The temporal change of economic-ecological phenomena results in the necessity of dynamic comparative analysis of objects, and the observation of the economic-ecological phenomena during different time periods. The analysis of sources of information concerning the environment indicates that such periods should cover selected years, as this is the fundamental cycle of making ecological information available[3]. A dynamic study makes it possible to take into account the changes and fluctuations which occur during the process of economic-ecological phenomena when evaluating the condition of the environment. Comparative studies should have a cross-dynamic analysis character, which is the most comprehensive form of multivariate comparative analysis.

The unique characteristic of economic-ecological system is also the manifold determination of actions concerning the environment and its protection. Consequently, comparative analysis of a set of objects in one qualitatively homogenous space of characteristics is not possible; but it is possible simultaneously in many spaces of variables corresponding to many economic-ecological phenomena. These phenomena are interconnected; therefore, it is necessary to define the space of a taxonomic study (classification) that is the set of properties (diagnostic characteristics) which describe the studied objects most comprehensively.

The aim of a taxonomic study can be realised by an assignment of the ordering of a set of objects or an assignment of the division (grouping) of a set. To order a set of objects according to the levels of the selected phenomena, taxonomic development measures are used. The taxonomic measures are synthetic variables, constructed on the basis of detailed diagnostic characteristics. The use of synthetic measures enables a numerical description of the complex phenomenon with the use of one value.

The classification of objects compared is based on the division of a set of objects into typological groups of similar objects in the way of specific criteria, or on the distinguishing of spatially coherent regions. The foundation of a classification are usually the distances between the objects compared, which constitute the measure of their similarity. It is also possible to classify objects based on the earlier prepared synthetic measures.

Empirical example

The subject of the following study was the anthropogenic impact on the environment of European countries, concerning the emission of air pollutants. The intensity of the impact on the environment was characterised using 16 indicators:

- the emission of greenhouse gases in percentage in comparison with the base year (w1),

[3] The detailed analysis of sources of ecological information and the ways it is made available is included, among others, in [8].

- the emission of acid pollutants in thousand tons per capita (w2),
- the emission of sulphur dioxide in thousand tons per capita (w3),
- the emissions of nitrogen oxides in thousand tons per capita (w4),
- the weighted emission of tropospheric ozone precursors in thousands tons per capita (w5),
- the emission of carbon monoxide in thousand tons per capita (w6),
- the weighted emission of greenhouse gases in million tons per capita (w7),
- the emission of carbon dioxide in thousand tons per capita (w8),
- the emissions of methane in thousand tons per capita (w9),
- the emissions of nitrous oxide in thousand tons per capita (w10),
- the emission of greenhouse gases in million tons of equivalent per capita (w11),
- the emissions of acidifying substances in thousand tons of equivalent per capita (w12),
- the emissions of ozone precursors in thousands tons per capita (w13),
- the emission of particulate pollution in thousands tons per capita (w14),
- the emission of transportation greenhouse gases in thousands tons per capita (w15),
- the emission of transportation ozone precursors in thousands tons per capita (w16).

The scope of the study covers 31 European countries, and the time range covers the year 2005. The source of the data is the EUROSTAT[4] database.

The aim of the study was to arrange the European countries according to the intensity of the impact on the environment.

Hierarchic classification, which is based on the linear ordering of the set of objects according to the selected research problem, was conducted. The set of objects are not measured directly but may be described according to, at least, two characteristics. This classification orders objects from *the best* to *the worst* (or vice versa) on the basis of the synthetic development index (Polish abbreviation: SMR), which is the aggregate of information included in specific characteristics, established for the classified objects [9].

In subsequent steps:

- the nature of characteristics was established - all of the studied features have a destimulant character (decrease is desirable),
- the matrix, that is the transformation of a destimulant into a stimulant, was standardised,
- the characteristics, which ensure the comparability of data characterised by different names, were normalised,
- Synthetic development measure (in Polish SMR) was defined with the use of the standardless formula (SMR value is the arithmetic mean of the value assigned to an object)[5].

The values for the chosen indicators for the surveyed European countries are presented in Table 1.

[4] The choice of the studied countries and the temporal scope was dictated by the availability of data. For the indicators selected, there was incomplete data for all European countries and later periods.
[5] The detailed discussion of the procedure of creating the SMR is beyond the scope of this study.

Table 1. The values of the chosen indicators describing the pressure on the environment (data for 2005)

	w1	w2	w3	w4	w5	w6	w7
Austria	14,379	1,201	3,218	28,876	66,781	100,336	11,364
Belgium	9,353	1,438	14,032	27,269	57,210	80,287	13,627
Bulgaria	6,855	4,711	115,998	30,080	67,133	95,383	9,084
Cyprus	218,107	2,683	56,662	23,092	50,362	54,820	13,148
Czech Republic	7,338	1,654	21,391	27,185	57,209	49,975	14,260
Denmark	16,946	1,878	4,040	34,036	75,622	109,410	11,744
Estonia	33,618	2,716	57,306	23,807	69,818	117,320	14,330
Finland	18,562	1,556	13,205	33,879	77,972	99,650	13,182
France	1,571	1,433	7,431	22,551	60,828	90,495	8,863
Germany	0,988	1,040	6,789	17,535	44,168	50,918	12,182
Greece	11,288	2,574	47,769	29,919	73,706	96,967	12,076
Hungary	6,883	1,304	12,797	20,111	49,026	58,133	7,943
Ireland	30,785	2,772	17,132	30,176	58,849	44,654	17,120
Italy	1,912	1,045	8,491	19,015	51,552	65,130	9,886
Latvia	18,643	0,798	1,552	17,473	64,645	142,024	4,826
Liechtenstein	3407,514	0,578	1,445	8,671	34,393	45,954	7,803
Lithuania	13,400	1,442	12,767	16,825	51,840	55,571	6,621
Luxembourg	218,763	0,889	6,353	5,919	23,155	26,451	28,814
Malta	361,340	1,565	44,702	22,326	37,848	2,061	7,922
Netherlands	6,096	1,038	3,818	19,923	39,035	33,327	12,986
Norway	23,511	1,359	5,228	41,638	110,224	97,216	11,679
Poland	1,797	1,965	32,008	21,242	59,362	87,323	10,121
Portugal	13,809	1,585	20,412	27,472	68,242	61,227	8,303
Romania	2,521	2,078	33,574	14,932	42,035	69,067	7,017
Slovakia	12,721	1,207	16,530	18,205	44,230	55,608	9,161
Slovenia	50,361	1,687	20,905	23,358	56,899	58,480	10,247
Spain	3,534	2,246	31,590	35,530	73,395	58,796	10,244
Sweden	10,287	0,916	4,404	20,046	54,448	67,523	7,424
Switzerland	13,742	0,790	2,347	11,436	33,184	45,005	7,254
Turkey	2,565	0,711	18,810	15,085	39,322	50,338	4,361
United Kingdom	1,405	1,253	11,759	26,970	53,825	39,766	10,911

Source: the author's study based on data from EUROSTAT [3].

SMR values for particular countries are presented in Table 2.

Table 2. The values of synthetic development measure (standardless formula)

Country	SMR value		Country	SMR value
Austria	1,70		Lithuania	2,16
Belgium	1,62		Luxembourg	2,33
Bulgaria	1,46		Malta	2,64
Cyprus	1,39		Netherlands	2,07
Czech Republic	1,54		Norway	1,44
Denmark	1,46		Poland	1,94
Estonia	1,31		Portugal	1,68
Finland	1,40		Romania	2,43
France	1,96		Slovakia	2,10
Germany	2,37		Slovenia	1,57
Greece	1,36		Spain	1,50
Hungary	2,03		Sweden	2,25
Ireland	1,20		Switzerland	2,96
Italy	2,09		Turkey	3,56
Latvia	2,83		United Kingdom	1,99
Liechtenstein	3,32			

Source: the author's study.

After arranging the table ascendingly according to the value of the measure a classification of objects from *the best* to *the worst* the following classification was achieved (Table 3).

Table 3. The hierarchy of objects according to SMR value

Country	SMR value		Country	SMR value
Ireland	1,20		United Kingdom	1,99
Estonia	1,31		Hungary	2,03
Greece	1,36		Netherlands	2,07
Cyprus	1,39		Italy	2,09
Finland	1,40		Slovakia	2,10
Norway	1,44		Lithuania	2,16
Bulgaria	1,46		Sweden	2,25
Denmark	1,46		Luxembourg	2,33
Spain	1,50		Germany	2,37
Czech Republic	1,54		Romania	2,43
Slovenia	1,57		Malta	2,64
Belgium	1,62		Latvia	2,83
Portugal	1,68		Switzerland	2,96
Austria	1,70		Liechtenstein	3,32
Poland	1,94		Turkey	3,56
France	1,96			

Source: the author's study.

From the research conducted it can be concluded that the biggest pressure on the environment, in terms of air pollution emission, is exerted by Turkey (SMR at the level of

3,56), and the lowest by Ireland, with the value of the indicator at the level of 1,20. Poland, in the classification of 31 countries, is placed on 15 place (SMR value = 1,94).

It should be noted that the anthropogenic impact should not be equated with the condition of the environment; anthropogenic impact means solely the influence of the planned and chance activities on the environment, and the condition of the environment is also determined by, among others, the undertaken preventive and repair measures.

Conclusions

1. The ordering or grouping of objects is not done for its own sake. The verified results of a taxonomic research should be a subject of factual analysis, as the main goal of classification or distinguishing of groups of objects is the facilitation of such an analysis and lending credit to it.

2. The classification with the help of taxonomic methods requires a precise specification of the diagnostic characteristics. The proper choice of such methods influences the research final results: the accuracy of evaluations and analyses, the precision of predictions and resulting from it, the accuracy of the decisions made on their bases. The set of diagnostic characteristics should be prepared in such a way that it characterises the main aspects of the studied phenomena in the most comprehensive way possible. Usually, we deal with a situation in which particular characteristics have a different informative value from the perspective of the problem analysed. The basic criterion of the evaluation of the usefulness of the difference in value should be their factual value, depending on the aim of a study. It should be remembered that taxonomic studies conducted on the basis of a set of characteristics, which does not include the most crucial characteristics of the phenomenon studied, do not bear an important research values and may lead to a misevaluation of reality.

3. The direct usage of diagnostic characteristics to determine the values of similarity measures of the objects implies the simultaneous assumption that all diagnostic characteristics are of equal value to the description of the classified objects, thus the importance of all the characteristics is the same. In the research concerning the society-economy-environment system such a course of action is not always justifiable, as in the sets of diagnostic characteristics there are usually items of different informative value from the perspective of the aim of a study. To account for the dissimilar importance of particular characteristics, weights should be constructed, to be subsequently used to determine the measures of similarity of objects (in other words, a valuation of diagnostic characteristics should be made).

4. The sources of information used should enable most comprehensive comparability of data in the spatial and temporal order.

In Poland, the Regional Data Bank.[1][6] is recommended as a source of information about the major information resources on the regional and local levels. The Regional Data Bank (Polish abbreviation: BDR) is an ordered set of information about the socio-economical, demographic, social and environmental condition, which describes voivodships, districts and municipalities as subjects of the social and territorial country organisation system. The subject scope of the BDR is the resultant of the identification of users and the analysis of their needs; the scope of the BDR was mainly determined by the administrative division of the country (the district being the basic unit of territorial division of the country and the seat of local government).

[6] Detailed information on the built and information resources of the Regional Data Bank are available on the main page of Central Statistics Office in the bookmark the Regional Data Bank: www.stat.gov.pl/bdr_n/app/strona.indeks

The database created for the BDR was built in the form of a catalogue of characteristics. The catalogue of characteristics is a set of standard (simple) data, and it enables the calculation of a number of derivative (complex) values – so there is a possibility to create derivative models. The organisation of the Bank makes it possible to create a series of aggregates of data and assures the possibility of the disaggregation in the spatial and temporal order.

References

1. Bank Danych Regionalnych: www.stat.gov.pl/bdr_n/app/strona.indeks (31.10.2009).
2. Becla A., Zielińska A., *Elementy statystyki i metod ilościowych*, I-Bis, Wrocław 2003.
3. Eurostat, the Statistical Office of the European Communities**:** http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home, (31.10.2009).
4. Grabiński T., Wydymus S., Zeliaś A., *Metody prognozowania rozwoju społeczno-gospodarczego,* PWE, Warszawa 1983.
5. http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Jevons.html (31.10.2009).
6. Kukuła K., *Metoda unitaryzacji zerowanej*, Wydawnictwo Naukowe PWN, Warszawa 2000.
7. Nowak E., *Metody taksonomiczne w klasyfikacji obiektów społeczno-gospodarczych*, PWE, Warszawa 1990.
8. Sej-Kolasa M., *Podstawy zarządzania informacją o środowisku*, Wydawnictwo AE, Wrocław 2002.
9. Sej-Kolasa M., Zielińska A., *Excel w statystyce. Materiały do ćwiczeń*, Wydawnictwo AE, Wrocław 2004.