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Erratum

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BUILDING INDICATORS OF SUSTAINABLE DEVELOPMENT WITH THE USE OF MULTI-CRITERIA DECISION MAKING METHODS

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Abstract: *An approach for analyzing big data is proposed with reference to sustainable development indicators (SDI), based on the application of combinations of various mathematical techniques. In particular, methods of multi-criteria decision-making for developing the SDI are described in the article. Examples of constructing UN SDI are given.*

Keywords: *System analysis, indicators of sustainable development, data mining, integral indicators, information support of expert activity, synergetic effect, decision support systems*

Introduction

The main approaches to construct United Nations Sustainable Development goals (SDG) are considered in [11]. In particular, 17 SDG adopted at the UN summit in New York in 2015 were presented in [1,2,11], This article focuses on Goal 3 (ensure healthy lives and promote wellbeing for all at all ages) as a model example. Each goal is split into several sub-goals, for which specific numerical indicators are calculated. Such a hierarchy naturally leads us to construct a two-level system of integral indicators for both the selected one and any other SDG, since their conceptual structure coincides. Goal 3 consists of eight basic and four additional sub-goals, which are measured by 27 initial indicators. For the analysis, big data from the UNSTATS database (unstats.un.org) was used. Since SDGs were introduced relatively recently, and methods for evaluating indicators continue to be actively developed, not all indicators contain enough data for large-scale analyses.

The proposed approach to designing sustainable development indicators (SDI) is closely related to that used in big data analyses. Let's consider some small examples. At the first stage of the project (2000–2015), a comparative analysis of the UN Millennium Development Goals (MDG) and the present UN Sustainable Development Goals (SDG) was carried out. Recent approaches to designing SDGs partly inherited the ways that were used for the UN MDGs, but at the same time they pointed out the interrelation of social, economic and environmental problems more widely both quantitatively and qualitatively. In addition, the country coverage is now much broader. The Millennium Development Goals were mainly focused on developing countries. Therefore, in the developed countries it is better to apply recent information technologies allowing to deal with the widest range of tasks.

For example, even the poorest segments of the population in developed countries actively make use of various mobile gadgets (smart phones, tablets), bank cards, etc., which results in the generation of vast amounts of information. This, in turn, allows collecting and processing huge amounts of personal data, which makes it possible, for example, to classify people by income levels, analyze consumer baskets, etc. Of course, processing such data, without the consent of the citizens themselves, is not yet legally and ethically worked out, but various applied computer systems already have the necessary algorithms for handling big data (for example, processing election ballots systems; messaging information about emergency situations, etc.).

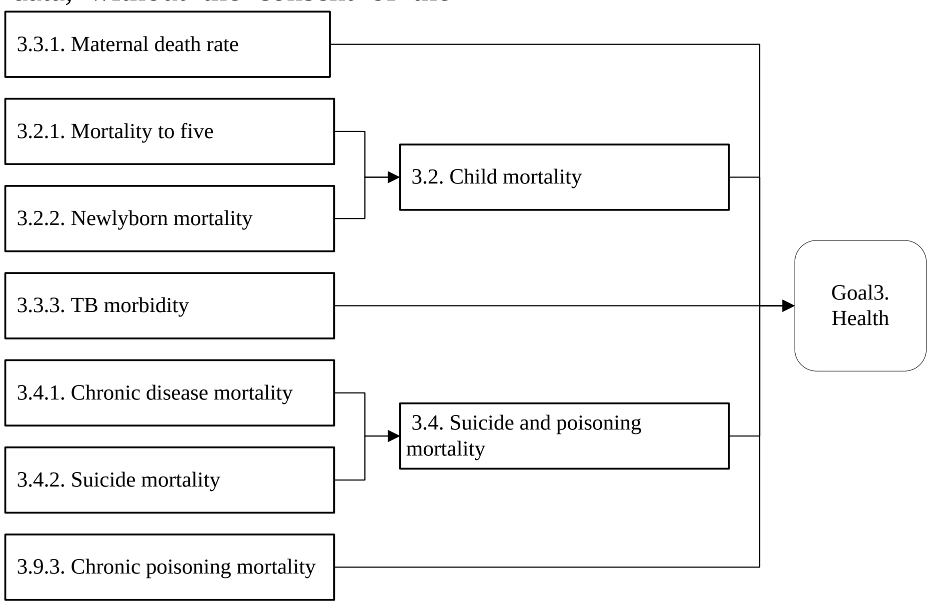

Figure 1. ***The Structure of Used Indicators for Goal 3***

In this regard, the initiative of the Institute of Electrical and Electronics Engineers (IEEE) on the development of draft standards for the ethics of artificial intelligence deserves great interest [13,14]. Within the framework of this initiative, a specific regulation is proposed for processing personal data, which is very promising for the development of various SDIs. In 2016, scientists from Stanford [12] developed a system for predicting levels of poverty in some regions of the world. This complies with requirements of one of the 17 goals proposed in the UN documents and is based on the analysis of images obtained from satellites.

In many of the poorest countries (Uganda, Malawi, Rwanda, etc.) it is impossible to carry out various socio-economic studies due to the incessant internal civil strife, epidemics of various diseases, destruction of basic infrastructure elements and for a number of other reasons. In addition, in many countries there are not enough resources to implement annual population census, collect and analyze socio-demographic data.

Accordingly, the rapid development of information technologies allowed to collect and pre-process huge arrays of various information and underline the relevance of big data analyses. The scientists from Stanford proposed an approach based on neural networks to analyze satellite images. It should be noted that on the Internet now you can find a large number of different and completely open data banks with satellite images of the Earth's surface. Thus, virtually all researchers are now able to independently process such satellite images and compare their results with the available data, such as the UN data, the results of the population census taken in various poor countries before the local wars, etc.

The essence of the methodology applied by the Stanford scientists was as follows. At the first stage, daytime images were analyzed and various human settlements were singled out on them. At the second stage, night imagery was analyzed, and the level of illumination of the settlements, identified at the first stage, was measured. The outcome made it possible to predict an increased level of poverty for those places where night-time lighting was less with a larger number of settlements. The results of the network under consideration were compared with socio-demographic data, which made it possible to assess how accurately the network predicted the level of poverty.

Thus, it is useful, and even advisable, to use several different independent tools at the same time for comparing results in order to build SDI.

1. Statement of the problem

The authors selected those indicators for which the database is available on as many countries as possible. Specifically, for Goal 3, seven indicators are associated with the five sub-goals (see Figure 1).

Considering selected indicators, the sample included 175 countries, data for which were taken for 2015. However, since the SDG are an ideological follow-up to the Millennium Development Goals [2], they inherit many of those indicators and the associated data collecting and accounting techniques. Therefore, it is also possible to carry out an interim analysis, starting from 2005, with regular five year intervals (that is, for 2005, 2010 and 2015) for the indicators under study. In addition, such an approach allows to supplement the integrated evaluation with new indicators as soon as information on them becomes available.

2. The concept of the problem decision

In order to make integrated indicators, the multi-criteria utility theory (MAUT) and the hierarchical order classification algorithm (ORCLASS) were used, which belong to the class of methods of verbal decision analysis (VDA) [7]. Comparisons of two or more different approaches to work out integrated indicators make it possible to obtain a synergistic effect (increasing the efficiency of a decision-making in handling multi-criteria problems) [3].

Since the majority of decision-making techniques is based on heuristic procedures that take into account the past experience and intuition of experts, and do not have a rigorous justification comparing the results obtained with fundamentally different methods make it possible to assess the quality and stability of the goal achievment.

The MAUT method allows to rank the investigated alternatives by constructing the utility function, most often in the form of a weighted sum of estimates for each of the indicators [4]. Such an algorithm is very simple in the computational and conceptual way and is effective with a large number of alternatives. However, the MAUT is very sensitive to the choice of algorithms for determining the weights of criteria, and its different algorithms can give different results. Another drawback of applying the weighted convolution method to the criteria is the significant difficulty of interpreting the results, since the inverse mapping from the utility function to the initial indicators is impossible.

To determine criteria weights, we used the method described by A.G. Raev [5]. It consists in determining the weight of each criterion on the basis of a selective standard deviation of the utility of all alternatives according to this criterion. The idea is that if the standard deviation is large, then the alternatives for this criterion differ significantly and this criterion is of greater interest in terms of the sample variability. For this method, there is no need to order or pairwise compare the criteria for preference. To normalize the weights a_k for each indicator k, each standard deviation is divided by the sum of all deviations:

$$a_k = \frac{\sigma_k}{\sum_k^K \sigma_k}$$

This method makes it possible to use selective distribution properties of the assessments without relying on the experts' opinion.

In comparison with the MAUT, VDA algorithms allow using in the initial verbal form the information obtained from experts, taking into account its consistency check [6]. The results obtained can be easily interpreted in the natural language and form logical decision rules. In general, the VDA method allows to take into account intrinsic human limitations in the information treatment, because they use qualitative (verbal) estimates of the properties of objects under study.

The ORCLASS method is designed to solve ordinal order classification problems [7]. In this case, a complete and consistent classification is constructed for the collection of all possible tuples of country estimates on the indicators under study, allowing one to assign any possible combination of estimates to one of the given classes. The procedure is carried out using the classification of previously found informative points by the decision-makers, which allow to indirectly classify the largest number of alternatives.

The application of the ORCLASS method presents significant difficulties if it deals with a large number of indicators and gradations on the ordinal scale of estimates, but this method is practically insensitive to measurement errors and let explain the results obtained using the natural language of the domain description. In order to reduce the complexity of the application of the ORCLASS algorithm for evaluating indicators, a simplified order scale of three values based on the Harrington scale was applied [8]:

Table 1.The utility and category assessment

Utility	Harrington	Simplified Scale
0-0.2	4	2
0.2-0.37	3	2
0.37-0.64	2	1
0.64-0.8	1	1
0.8-1	0	0

In this case, the gradations of the initial indicator evaluation are as follows: 0-Good;

1-Satisfactory; 2-Bad (Table 1).

The initial utility was estimated in the same way as in the MAUT method, with preliminary elimination of emissions. As a software for the algorithm ORCLASS, we used the package ORCLASS, developed by the Institute for Systems Analysis of the Russian Academy of Science (ISA RAS) [9,10]. To reduce the dimensionality of the feature space, integrated indicators for sub-goals were previously constructed, as shown in Fig. 1. Furthermore, on the basis of five indicators with three gradations of estimates, a classification was built for five classes (in accordance with the second column of Table 1). Thus, each country could end up with one of the following: 0 – Excellent; 1 – Good; 2 – Satisfactory; 3 – Poor; 4 – Unsatisfactory.

3. Realization of the concept

To compare the correspondence of the final estimates obtained with the two algorithms, the results achieved with the MAUT were translated into a categorical scale in accordance with Table 1. It is shown that if the described methods are applied, the classification of countries corresponds with each other in 51% of cases. Thus, the classes of 51% of the countries correspond exactly for the two algorithms. At the same time, the relative difference (that is, by how many notches on the five-point scale countries that fall into different classes differ) was about 14%. This means that most of the countries with different classes are on the adjacent notches of the five-point scale. A total of 10 countries differ by two notches (for example, Afghanistan received a score of two for MAUT and four for ORCLASS). Differences in more than two gradations of the scale of assessments were not revealed.

Conclusion

Thus, there are no critical differences between the results of the two algorithms for most countries. However, the ORCLASS method allows through the application of expert rules in some cases to clarify the assigned assessment. For example, if a country has an excellent score for all but one indicator and one indicator is unsatisfactory, the MAUT- by means of averaging - refers the country to a better class, while expert classification reduces the score to a good one.

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