Comparison of sustainable environment indicators aggregation possibilities by means of chosen Petri nets species

ROBERT BAŤA, ILONA OBRŠÁLOVÁ, TICIANO COSTA-JORDAO
Faculty of Economic and Administration, Institute of Public Administration and Law
University of Pardubice
Studentská 95, 532 10 Pardubice
CZECH REPUBLIC
robert.bata@upce.cz; ilona.obrsalova@upce.cz; ticiano.costa-jordao@upce.cz

Abstract: There are dozens of sets of indicators that try to solve the problem of sustainable environmental development at local, regional, national and global levels. Currently, there are two approaches under development: policy-based and capital approach. This article is focused in the evaluation of sustainable environment on regional level, where the number of indicators had to be, for purposes of strategic decision-making, limited only to the most important ones. It is possible to solve the problem by Petri nets. The result shows an example of aggregation for a group of indicators that provides useful information, which support decision-making for regional development management.

Key -Words: Modells comparison, sustainable development, indicators, prediction, aggregation, Petri nets, regional development.

1 Introduction

The term sustainable environment has many definitions [9,12]. We seek for balance among the environmental, economical and social development pillar on not only local, but also national and global level, when trans-generation equity is required. Great scale of possibilities how to express that comes from individual opinion trends such as weak and weak sustainability, strong and very strong sustainability. There are indicators describing individual partial problems or they focus on the synthesis of all three pillars state. Another approach is sorting of indicators on policy based, capital approach and stock and flow approach. One of well-known scopes of observation is OECD pressure - state - response.

Research centers from all over the world try to create indicators for monitoring and evaluating development by processing elementary measured or observed data and creating of derived and aggregated indicators. Preparation and elaboration of indicators relevant for certain management level is necessary for the decisive sphere.

Problem complexicity brings necessity of solution from many aspects. One of designed approaches [9,10,12] brings these types of indicators: level indicators, capital indicators, input/output indicators, structural criteria (efficiency and distributional disparities) and response indicators.

Capital approach works with five capitals: financial capital represented for example by stocks, bonds, currency deposits; produced capital such as machinery, buildings etc; natural capital in form of natural resources, ecosystems etc.; human capital such as educated work force and social capital in form of social institutions and networks [1,9]

Many more possibilities of solving the problem are formed by the necessity of interpretation by aggregated indicators. Indicators such as ESI, HDI, ecological footprint and many more [9,10] were formed.

We can state that each indicator has both strengths and weaknesses. Therefore, we cannot work with only one universal indicator and we have to respect a great variability of sustainable development problems.

2 Problem Formulation

The article is devoted to the problem of evaluation of regional development sustainability. Region in this context means one statistical unit NUTS II. In strategic documents from this sphere [14] we can find hundreds of indicators constructed mainly for evaluation of regional development policy and a lot of possibilities of their elaboration[5,7,15]. The capital approach was quite difficult to apply, considering current state of the theory and possibility of transforming to indicators in all necessary segments of sustainable development. A great range of descriptive indicators results in the fact that individual problems are not evaluated comprehensively within mutual relations of sustainable development pillars. For purposes of decision-making [4] of regional governments it is necessary to elaborate the issue even more with synthetic information and to aggregate indicators. More than one organizational unit provides information and works with indicators; that is why we need to find a method, which would allow us to lively resolve needs of various management levels from various branches.

More methods can be used for indicator aggregation, for example statistic- analytic method, like regression analysis, cluster analysis, Cronbach coefficient alpha etc. and statistic - descriptive methods like aggregation techniques, experts decisions, efficiency frontier method etc.[6,10,11]. In this article we introduce utilization of Petri nets.

3 Problem Solution

3.1 Petri nets

In the Petri Nets theory it is stated that a Petri net (further just PN) has to, if it is under requirements, satisfy characteristics of liveliness, finiteness and conservativeness or conservativeness with respect to weight vector [3,8]. This requirement is, in terms of theoretical requirements to PN, fully understandable, because it has significant determinative effects on function of these nets and also on possibilities of working with them.

For practical purposes without view on further development it seems appropriate to use the option of creating model by means of PN, which does not satisfy the characteristics. In light of options of following analyses and their characteristics; the result is then limited to for example statement that current net is non-live, infinite and is not conservative, eventually it does not satisfy any other requirements; on the other hand we can, in some reasonable instances, use these characteristics and so reinforce some modeling abilities of this tool and also plasticity of this model itself of created model in communication with people who might not necessarily be experts in Petri net problem.

For presentation of utilization they selected aggregation of indicators of sustainable development by means of non-live Petri nets. Indicators for selected (Pardubice) region within the Czech Republic were aggregated. Timelines were taken over from statistic yearbooks; selected indicators were detached based on correlation of all available timelines within selected pillar. The social pillar was chosen because the environmental and economic pillar data showed high rate of correlation; that is why there would be insufficient number of input indicators for model design. The goal was to create a model based on PN which could simulate development of aggregated indicators conformable with calculated values describing current state and which would enable to predict this state for the same number of years. Aggregated indicator of current state was calculated as weighted sum where weights of individual aggregated values were weights set by experts on social problems within region by means of Fuller triangle. PN was defined as ordered tuple $N = (P, T, F, W, K, M_0)$.

1) (P, T ,F) is ultimate net, where
P represents a set of all places of N net N (for example for net with four places $P = \{p_1, p_2, p_3, p_4,\}$);
T represents a set of all transitions, while sets P and T must be mutually disjoint.
F $\subseteq (P \times T) \cup (T \times P)$ is a union of two binary relations; F is called flow relation of N net;
2) W: $F \rightarrow N \setminus \{0\}$ evaluation of net graph, which defines weight of each arc;
3) K: $P \rightarrow N \cup \{\omega\}$ is view defining capacity of each place, even unlimited capacity;
4) M_0: $P \rightarrow N \cup \{\omega\}$ is initial marking of each place, while place capacities has to be honored.

3.2 Parameters design

Weights of individual indicators were set also in PN model by means of Fuller triangle. Values are multiplied by hundred and established to the model. These indicators show how significant role these indicators play within the sustainable development social pillar. In Table 1 there are timelines of some uncorrelated non-aggregated indicators of the sustainable development social pillar from Pardubice region within individual years and weights established to the model.

Table 1 Indicators and weights

Indicators	Indicator weight	2001	2002	2003	2004	2005	2006
Number of inhabitants living in towns	13	312420	311 518	309 863	309 234	308 675	311 251
Number of newcomers	13	3236	4 329	4 847	4 629	4 996	5 525
Number of deceased	0	3734	4 394	5 186	4 443	3 998	3 882
Number of inhabitants with secondary school education	20	177465	174 844	178 391	181 210	174 878	180 403
Number of inhabitants	20	112200	112 100	111 900	111 800	112 000	112 400
Number of economic active inhabitants	34	259500	255 300	254 000	258 000	255 800	254 800

Source[13]

Then we calculated value of aggregated social indicator for individual years, these values are stated in table 2. The calculation is performed by multiplying indicators with their weights. These values were counted up in the Table 2 and divided by 100 so that they can be expressed in percentage.

The model which was constructed using this data was implemented in HPSim environment. For purpose of simplification the established values were divided by 100 and rounded off. Values were in the model used as weights of their relevant edges.

In Fig. 1 there is model for aggregation of selected social indicators illustrated. That allows also prediction of development of aggregated indicator.

Table 2 Aggregated social indicator

	2001	2002	2003	2004	2005	2006
Aggregated social indicator	187198	185251	185330	187124	185125	186374

Source: [own]

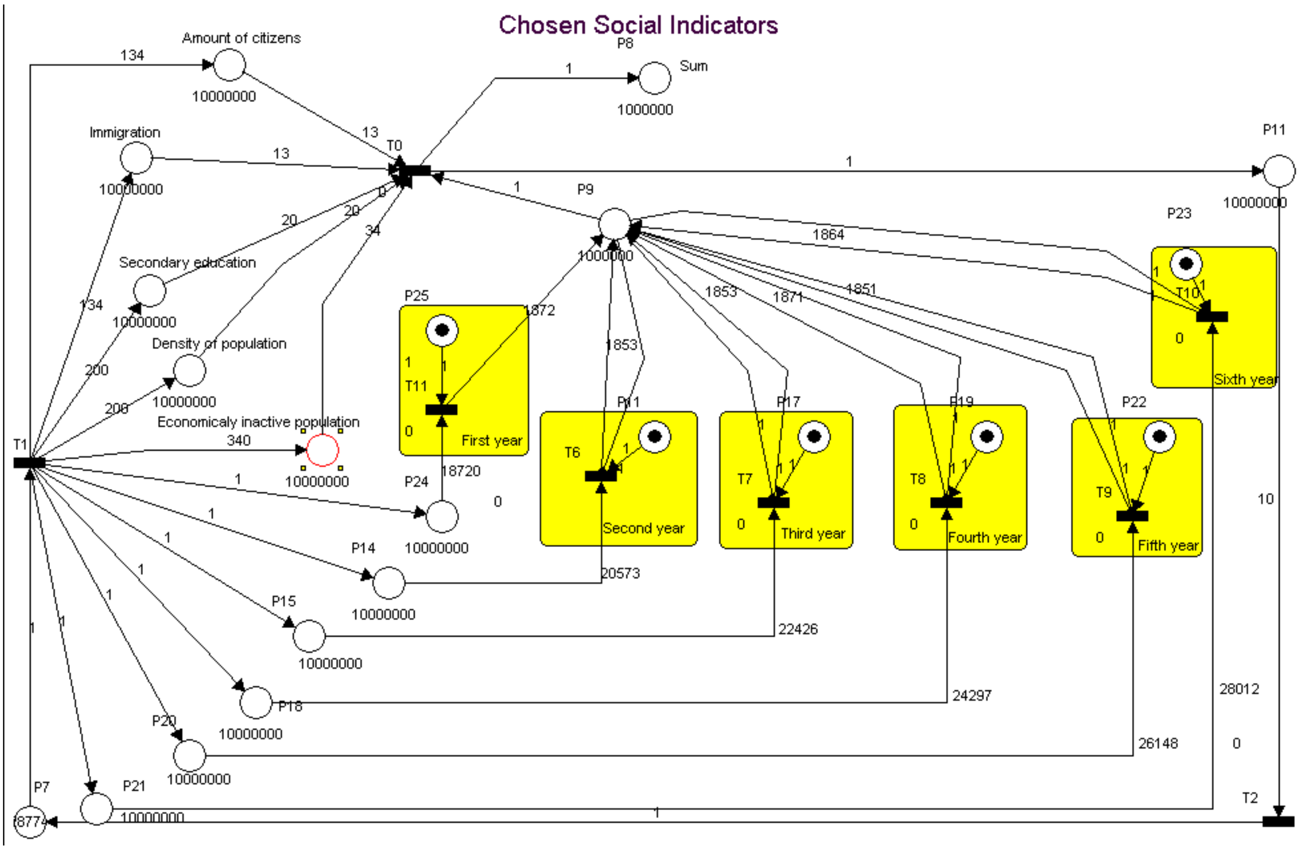

Figure 1 Model for aggregation of selected social indicators in HPSim environment Source: [own]

Initial marking was set empirically, as shown in Table 3.

Tab. 3 Initial PN marking

P7	P8	P9	P11	P17	P18	P19	P20	P21	P22	P23	P25
28774	0	0	1	1	0	1	0	0	1	1	1

Source: [own]

Table 4 shows the place capacity. The purpose of the large capacities set in some places was to keep the capacity unlimited. Because the HPSim environment doesn't allow an unlimited marking in places, the capacity for those places was set high.

Tab. 4: The Capacity of Places

P1 Amount of citizens	P2 Immigration	P3 Secondary education	P4 Density of population	P5 Economically inactive population	P7	P8
10000000	10000000	10000000	10000000	10000000	30028000	10000000
P9	P11	P14	P15	P16	P17	P19
10000000	10000000	10000000	10000000	10000000	1	1
P20	P21	P22	P23	P23	P24	P25
10000000	10000000	1	1	1	10000000	1

Source: [own]

Most of locations had their capacity set to a very high number (1000000), since environment does not allow setting infinite capacity. The purpose of this measure is to prevent deadlock for insufficient space.

In Table 5 we illustrate a summary of model outputs for individual years and their cumulated count for these years.

Year	Output for year	Cumulated count
2001	1872	1872
2002	1853	20573
2003	1853	22426
2004	1871	24297
2005	1851	26148
2006	1864	28012

Table 5 Summary of outputs in HPSim program, source: [Source: own].

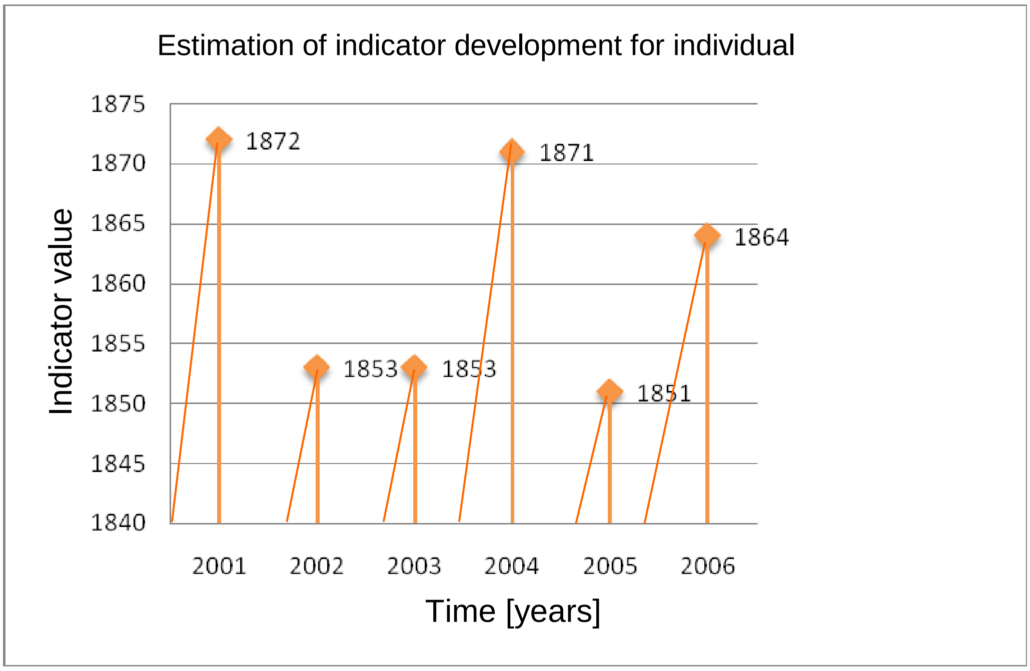

Figure 2 Estimation of indicator development for individual

By means of the model we simulated development referring to calculated values of aggregated indicator from empiric data in table 2. The model describes current state well, after change of input data it is possible to use the model even for prediction. Results of aggregations see Fig.2. It is possible to recognize increasing of indicators values during the simulated years. The growth indicators during the year should be interpreted in accordance with the individual aggregated variables. The increase in the demand for employed residents in the region cannot be perceived as evidence due to the gradual increase of work demanded but due to increasing number of working hours during the year. Similarly, it is possible to measure the indicator either for a longer or a shorter period of time.

Used Petri net is not live, by definition, whose lifetime is on level one, which is caused by transitions of determinative characteristics for individual years usable only once. After achieving the goal, modeling by a live Petri net on level 4 was found to be troublesome when it had to be graphically illustrated by the process of aggregation.. This net was very sophisticated, even though it is purposeful to be engaged in possibilities of simulation of development of such set indicators even by live PN.

Another possibility for the application of live PN is to build within the HPSim environment the graphic expression of aggregation due to its characteristics to predict the evolution of aggregate indicator without a graphical representation of aggregation through its direct model as shown in Figure 3.

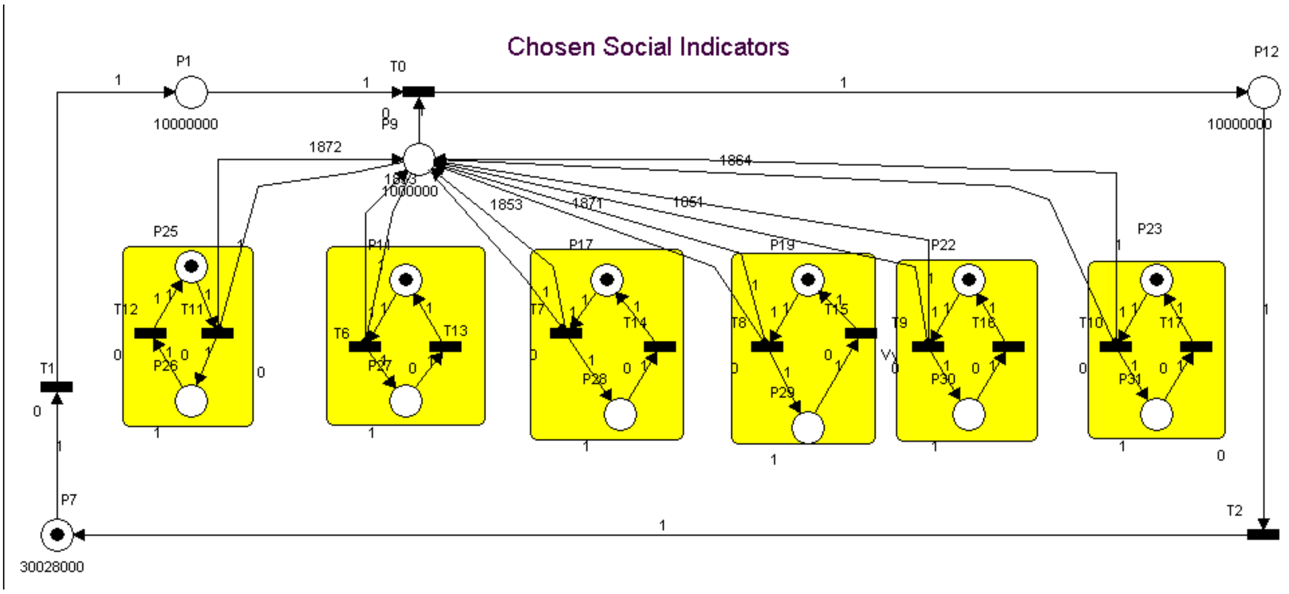

Figure 3 Example of a live Petri net model for simulating the development of aggregate indicators.

In this case, the model is generated based on parameters defined during the development of an indicator for the future years. Model parameters are as follows.

Tab.6 Initial Marking

P1	P7	P9	P11	P12	P17	P19	P22	P23	P25	P26	P27	P28	P29	P30	P31
0	1	0	1	0	1	1	1	1	0	0	0	0	0	0	0

[Source: own]

Tab. 7: The Capacity of Places

P1	P7	P9	P11	P12	P17	P19	P22
10000000	30028000	10000000	1	10000000	1	1	1
P23	P25	P26	P27	P28	P29	P30	P31
1	1	1	1	1	1	1	1

[Source: own]

Net is k-bounded, value k=1879, thus $\forall M \in |M0\rangle : M(p) \leq 1879$.

Net is nor conservative nor conservative with regard to weight vector, the liveness of each transition is at the level 4.

The tabulated simulation results with live PN model output is presented in the Table 8. Values with a white background are generated based on empirical comparable data, whilst values with shaded background are obtained from the model predicted data.

Tab. 8 Live PN model output

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1853	1851	1853	1864	1851	1871	1871	1872	1864	1864	1853	1872

[Source: Simulation Data generated by HPSim Jan-09-2010 14:11:51]

Data listed in Table. 8 are graphically represented in Figure 4.

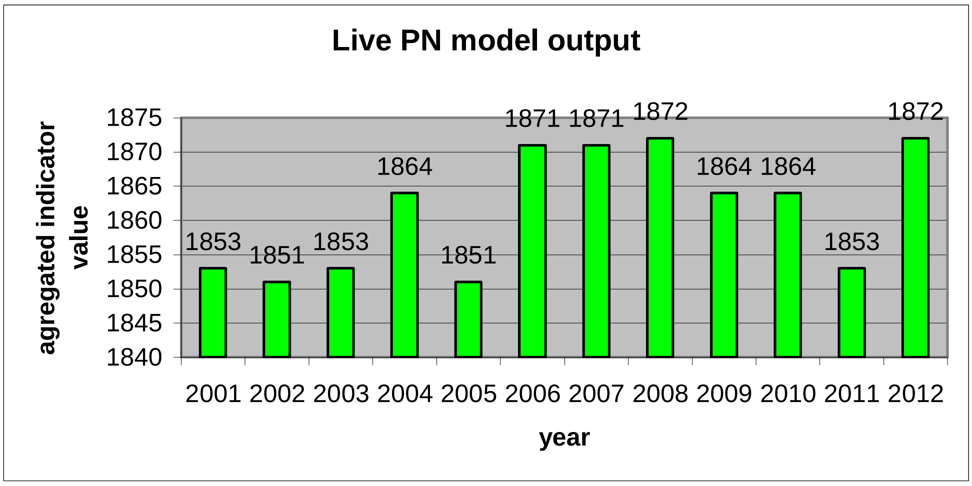

Fig. 4 Gpahical representation of Live PN model simulation output

Parameters of the model! The advantage of this simplification is the possibility of using live Petri net, which allows the prediction of the development of aggregate indicator for the future given the fact that this is precisely a live network. Data can then be generated to any desired number of years. There are, therefore, eliminating restrictions on the previous model, referred to in Figure 1 when the number of years of predictable model is limited to 6. A certain disadvantage of this proposed model is the fact that the results must be processed in a separate spreadsheet calculator, since the model provides only information on the value of the aggregate indicators for a certain number of time units. In terms of calculation, it is possible to calculate values for years, as well as for months, weeks or even more years at one time. The first variant of the model, while also placed certain requirements on the attribution of values, it has shown a much simpler calculation.

The disadvantage of the model in Figure 3 is the fact that it does not include aspects related to the change of priorities set by Fuller triangle, so for any change that might happen, it will be more difficult to adapt the model. Conversely, the construction of inanimate PN in Figure 1 can satisfactorily simulate the situation when changes occur in the setting of priorities of regional policy. However, in this case, the possibility of prediction of future developments is very limited. Due to the type of network that is supported by the HPSim environment, it seemed more appropriate to adopt live Petri net modeling in that case, whilst it can be expected that inanimate variant aggregation model is more appropriate in an environment in which the chosen type of network can better meet the requirements set.

To this end, it was chosen Umberto environment that enables the creation of models using hierarchical colored PN. The model proposed by inanimate colored PN in the Umberto environment is shown in the Figure 5.

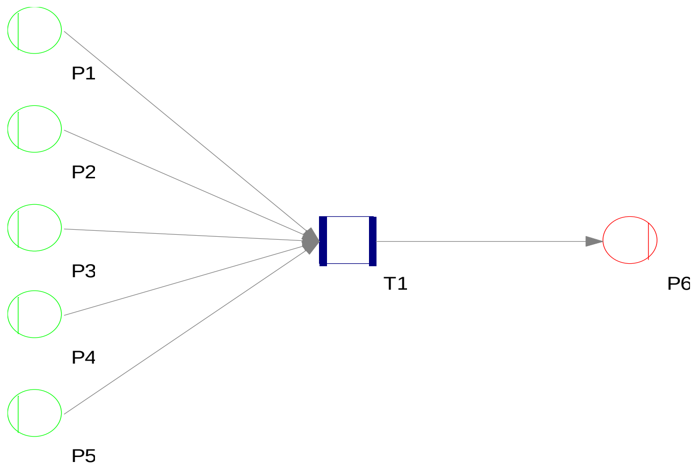

Fig. 5 Model for the aggregation of selected indicators expressed as inactive PN in the Umberto environment.

This type of net enables to simulate, based on the parameters of a given environment, the initial conditions specified in the output parameters. Whereas the prediction does not perform very well and is very dispensable to calculate in MS Excel environment, solving the given tasks through selected manual tools is seen as least appropriate.

An advantage, however, can be pointed out with the possibility of setting the share of input parameters on output and greater clarity in comparison to Excel. The advantage here is undoubtedly the mentioned illustration that can be used to communicate with third parties and as support for the assignment model using a live PN.

4 Conclusion

In this work various methods for the aggregation of sustainable environmental indicators are compared A simple problem of group of demographic data that characterize development in the selected region was aggregated as one of possibilities of indicators processing for decisive sphere. The solution also enables simulation and future development prediction.

In this study, three possibilities of aggregation of sustainable development indicators were compared: the implementation of an inanimate P/T PN (liveness of some transitions to level 1) in the HPSim environment, the implementation of a live P/T PN in the HPSim environment and the implementation of an inanimate colored PN in the Umberto environment. The comparison of the results showed that models using P/T PN with at least some of the transitions live on the level 4 offer in comparison to commonly used methods the possibility to simulate the future development, which represents the contribution of PN use for such purposes.

This work was supported by the scientific research project of Ministry of Environment, Czech Republic under Grant No SP/4i2/60/07 Indicators for valuation and modeling of interactions among environment, economics and social relations.

References:

[1] Budiš P.,Štědroň B., Elektronické komunikace. Magnet Press Slovakia, 2008

[2] Cornel L, Mirela L., The quantification of the sustainable development at local level. WSEAS Transactions on Business and Economics 6, No. 5, 2008, pp. 310-319

[3] ČEŠKA, M., Petriho sítě. Brno: CERM, 1994.

[4] Encheva,S., Tumin S.:Automated Decision Support System Based on Ordered Sources. WSEAS Transactions on Information & Applications, Issue 4, Volume 5, April 2008, pp. 356-364, pp.1448-1457, ISSN: 1790-0832

[5] Hajek,P., Olej,V.: Air Quality Indices and their Modelling by Hierarchical Fuzzy Inference Systems. WSEAS Transactions on Environment

and Development, Issue 10, Volume 5, October 2009, pp.661-672, ISSN: 1790-5079

[6] Hrach K., Mihola J., Metodické přístupy ke konstrukci souhrnných ukazatelů. Statistika, No. 5, 2006, pp.389 - 418

[7] Jirava P., Krupka J., Kasparova M.:Systems Modeling on the Basis of Rough and Rough-Fuzzy Approach. WSEAS Transactions on Information & Applications, Issue 10, Volume 5, October 2008, ISSN: 1790-0832

[8] Machačová I., Možnosti agregace indikátorů udržitelného rozvoje pomocí Petriho sítí. Faculty of Economics and Administration, University of Pardubice 2009

[9] Measuring Sustainable Development. Report of the Joint UNECE/OECD/Working Group. United Nations, New York and Geneva, 2008. Available http://www.oecd.org.dataoecd/30/20/41414440.pdf [14.09.2009]

[10] Moldan B., Hák T., Kovanda J., Havránek M., Kušková P.: Uspějí agregované indikátory při měření environmentální udržitelnosti? Statistika , No. 5, 2005. pp. 125-135

[11] Munda G.:Measuring Sustainability: A Multi-Criterion Framework. Available on http://www.springerlink.com/content/j15815254p411qw2/ [20.10.2009]

[12] Perez A. G., Hernandez Polez M.: Review of Sustainable Development Indicators. Case Study: Bolivarian Republic of Venezuela - Statistical Information for Year 2005
WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, Issue 8, Volume 5, 2009

[13] Regionální rozdíly v demografickém, sociálním a ekonomickém vývoji Pardubického kraje v letech 2000 až 2005. Available on http://www.pardubice.czso.cz/xe/edicniplan.nsf/p/13-5307-06 [20.10.2009]

[14] The Czech Republic Strategy for Sustainable development. Available on http://www.mzp.cz/C125750E003B698B/en/czech_republic_strategy_sd/$FILE/KM-CR_SDS_eng-20041208.pdf [20.10.2009]

[15] Zovko M., Butuci J.: Croatian Environment Information System - Estimation of Usage of Environmental Data and Information. WSEAS Transactions on Environment and Development, Issue 11, Volume 5, November 2009, pp.685-694, ISSN: 1790-5079