Sustainable environment indicators and possibilities of their aggregation by means of Petri nets

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Abstract: There are dozens of sets of indicators, which try to resolve the problem of sustainable environment development on different levels from local to global. Currently, there are two approaches under development: policy based and capital approach. This article engages 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 is example of aggregation for group of indicators, which would allow us to give information to regional development management in form usable for superior decision-making.

Key -Words: sustainable development, indicators, aggregation, Petri nets, regional development, strategic decision making

1 Introduction

The term sustainable environment has many definitions [6,9]. 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 [6,7,9] 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 [1,6]

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 [6,7] 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 [11] we can find hundreds of indicators constructed mainly for evaluation of regional development policy. 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 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.[4,7,8]. 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 [3,5]. 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 $\subseteq (P \times T) \mathbf{U} (T \times P)$ is a union of two binary relations; F is called flow relation of N net;
2) W: F → N \ {0} evaluation of net graph, which defines weight of each arc;
3) K: P → N $\mathbf{U}$ {ω} is view defining capacity of each place, even unlimited capacity;
4) M_0: P → N $\mathbf{U}$ {ω} 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[10]

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]

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 4 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

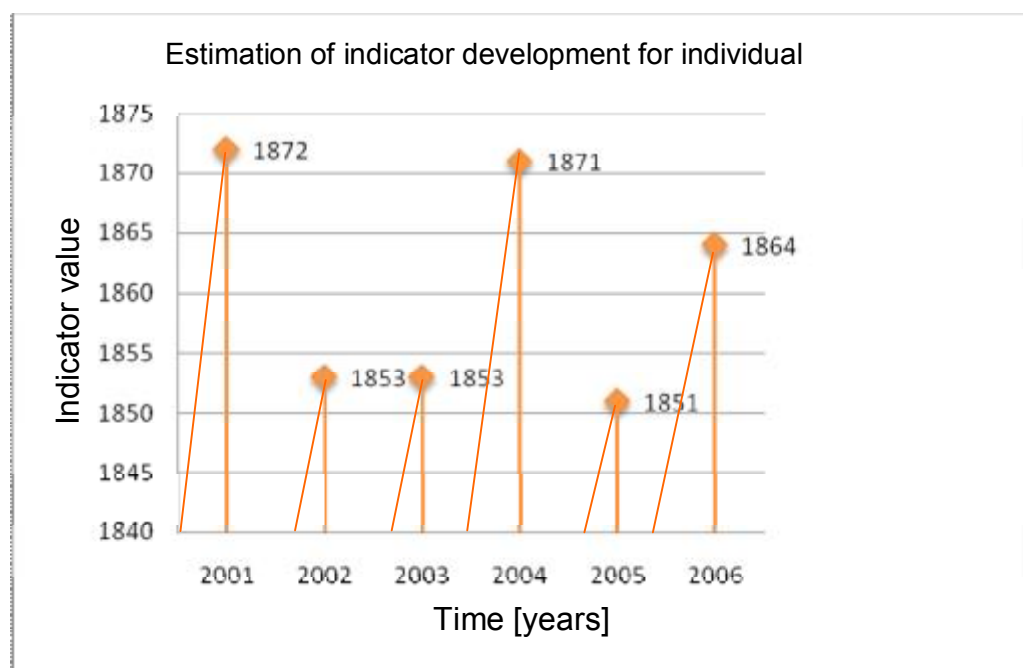Table 4 Summary of outputs in HPSim program, source: [Source: own].

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 .

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 quite problematic. 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.

4   Conclusion

Work with variously aggregated indicators of sustainable environment is, in term of theory and needs of practice, a very interesting area which needs to be even more developed. 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. Live Petri nets utilization would be most fitting.

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