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COMPARATIVE ANALYSIS OF THE INFORMATION SOCIETY DEVELOPMENT LEVEL IN THE POVIATS OF THE PODKARPACKIE VOIVODSHIP

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Abstract: The aim of this paper is to compare the IS development in the poviats of the podkarpackie voivodship. The synthetic development measures were determined according to: the multiplicative aggregation of indices and the TOPSIS method. Two levels of aggregation and weights determined by the AHP method were used. The values of the indicators were calculated based on the results of surveys carried out in the poviats of the podkarpackie voivodship within MNiSW research project "Determination of intra-regional disparities in the information society development".

Keywords: information society, information and communication technologies, synthetic measures, information society development level

INTRODUCTION

In the studies of the information society (IS) one of the main areas of research is comparative analysis of the level of development in different territorial units. In these analyzes quantitative methods are used, i.a. indices, that can be divided into core indicators and composite indices (CI) [ITU 2012, OECD 2011, United Nations et al. 2005]. Many international organizations and research companies for the past thirty years have offered and updated different sets of indicators to measure development of the IS and scope of use of the Information and Communications Technologies (ICT) (some of them are characterized in [Goliński 2011]). Majority of these indicators are indicators for measuring development of the IS in the countries (NUTS1) and are not suitable for smaller territorial units such as NUTS3 or LAU, because of their specific nature. Thus for smaller units, it is necessary to develop other sets of indicators which take into account their specific.

Composite indices have increasingly been accepted as a useful tool for performance comparisons, benchmarking etc. in various fields such as economy, environment and society [OECD 2008, IANIS+ 2007]. Their usefulness depends heavily on the underlying construction scheme, so a problem faced by researchers is to determine the most suitable method. Technically, CI is a mathematical aggregation of a set of sub-indicators for measuring multidimensional concepts that cannot be captured by a single indicator [OECD 2008]. There are many methods developed for constructing CI (see i.a. [OECD 2008, Panek 2009, Młodak 2006, Strahl 2006]). It is worth noting, that in recent years also methods for multiple criteria decision analysis (MCDA), e.g. AHP, ANP, TOPSIS, have been applied to construct CI.

The aim of this paper is to compare the IS development in the poviats of the podkarpackie voivodship.

RESEARCH METHODS AND EMPIRICAL DATA

Composite indices construction involves the definition of study scope, selection of underlying variables (core indicators), data collection and preprocessing, weighting and aggregation of core indicators and post analysis of the derived CI (see i.a. [Panek 2009, OECD 2008, Młodak 2006]).

To compare level of the IS development in the poviats[1], we used (as a data source) results of surveys carried out within MNiSW research project "Determination of intra-regional disparities in the information society development", i.e. data from questionnaires completed by 3670 households and by more than 11 100 residents (aged from 16 to 74 years) of the rural poviats of podkarpackie voivodship.

To measure level of the IS development, we applied 22 core indicators, which are related to five pillars (aspects) of the IS (see table 1). These aspects correspond to three stages in the ITU model of ICT development process towards the information society [ITU 2012] i.e.: ICT readiness (infrastructure, access), ICT use (intensity) and partially ICT impact (outcomes).

These indicators were selected primarily on the basis of their substantive meaning, statistical criteria were also used. Indicators values were not comparable to each other and it was necessary to normalize them. All the core indicators were measured using a ratio scale, so the quotient mapping was applied. As reference values we took value of 100 (for some indicators) or sum of the arithmetic mean and three standard deviations. Adoption of three instead of two standard deviations was due to large differences between values of some indicators. Moreover, to diminish the effect of large number of outliers at the high end of the value scale, values of indicators having high right asymmetry were transformed by square root function.

[1] Poviats are the second-level units of local government and administration in Poland (i.e. local administrative units LAU1, previously called NUTS4).

Table 1. Pillars (sub-indices) and core indicators included in general indices and their weights determined by the AHP method

Pillars (sub-indices) and core indicators	Weight
1. Residents and households readiness for functioning in the information society:	0,10
percentage of households with a desktop computer or a laptop	0,10
percentage of households with the Internet access	0,14
percentage of households with the Internet access having a broadband connection	0,22
average number of computer-related skills held by residents	0,31
average number of skills related to the use of computer networks held by residents	0,23
2. Scope of use of computers by residents:	0,24
percentage of individuals who regularly (i.e. at least once a week) use a computer	0,14
percentage of individuals who regularly use a word processor	0,18
percentage of individuals regularly using a spreadsheet	0,33
percentage of individuals using a database software at least once during the three months	0,35
3. Scope of the Internet use by residents:	0,10
percentage of individuals regularly using the Internet	0,24
percentage of individuals who regularly use e-mail	0,31
percentage of individuals who receive files from the Internet at least once in three months	0,14
percentage of individuals who regularly use instant messaging	0,31
4. Scope of use of e-services offered in the Internet by residents:	0,45
percentage of individuals who make purchases in the Internet at least once in the three months	0,24
percentage of individuals regularly using the Internet to access their bank account	0,36
percentage of individuals who at least once during the three months search the Internet for purchase or sale offers of real estate, cars, etc.	0,09
percentage of individuals who at least once in three months seek, book or buy on the Internet offers such deals	0,22
percentage of individuals regularly receiving information about cultural events from the Internet	0,09
5. Scope of use of e-government services by residents:	0,11
percentage of individuals who at least once in three months contact via the Internet with the public administration (government or local government)	0,24
percentage of individuals submitting tax returns via the Internet	0,44
percentage of individuals using the Internet in dealing with matters relating to personal documents	0,19
percentage of individuals who contact via the Internet with the health services	0,13

Source: own elaboration based on surveys

Two levels of aggregation were applied i.e.: core indicators into sub-indices and sub-indices into general indices. At the first stage of aggregation, we used two different methods: weighted product method (which is one of the "classical" methods for the construction of CI) and the TOPSIS method.

In weighted product method, multiplicative aggregation is applied and composite indices P are calculated as the weighted geometric mean, i.e. according to the formula:

$$P_i = \prod_{j=1}^{m} (x_{ij})^{w_j} \tag{1}$$

where x_{ij} – normalized value of the j-th core indicator for the i-th poviat, w_j – weight assigned to j-th core indicator, m – number of core indicators.

The values of the sub-indices were determined as the weighted geometric mean instead of frequently used the weighted arithmetic mean, because in case of the additive aggregation there is complete substitution of aggregated indicators (which means that low values of some of indicators are "fully compensated" by a sufficiently high values of the other). Whereas, the geometric aggregation is a less compensatory approach, which contributes to take actions to improve underperforming dimensions.

The TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is based on the concept that the best alternative (or item, e.g. poviat) should have the shortest distance from the ideal one and must have greatest distance from the negative one. A detailed description of this method can be found i.a. in [Rao 2010, Wysocki 2010, Deng et al. 2000]. We defined as ideal poviat – poviat with maximal values of core indicators and as negative-ideal poviat – poviat with minimal values of them, so composite indices T are calculated as:

$$T_i = \frac{\sqrt{\sum_{j=1}^{m} w_j (x_{ij} - \min_i \{x_{ij}\})^2}}{\sqrt{\sum_{j=1}^{m} w_j (x_{ij} - \min_i \{x_{ij}\})^2} + \sqrt{\sum_{j=1}^{m} w_j (x_{ij} - \max_i \{x_{ij}\})^2}} \tag{2}$$

where x_{ij} – normalized value of the j-th core indicator for the i-th poviat, w_j – weight assigned to j-th core indicator, m – number of core indicators.

Both in the weighted product method, as well as, in the TOPSIS method, results can depend strongly on the selected weights. In literature several weighting methods are proposed, e.g. equal weights, weights based on statistical methods and weights based on public/expert opinion (see i.a. [Panek 2009, OECD 2008, Wysocki 2010]). One of methods for calculating the weights in MCDA is the method of AHP (Analytical Hierarchy Process), in which measures of importance of criteria (or weights assigned to indicators) are determined on the basis of comparisons of them to each other in pairs by means of a rating scale introduced T. L. Saaty in the 1970s. A detailed description of this method can be found i.a. in [Rao 2010, Wysocki 2010]. The AHP method was used to determine weights w_j in

formulas (1) and (2). Pair-wise comparison matrix was established on the basis of author's knowledge about the substantive importance of particular indicators.

At the second level of aggregation, sub-indices obtained by both the weighted product method, as well as, in the TOPSIS were aggregated by the multiplicative method with weights determined by the AHP method.

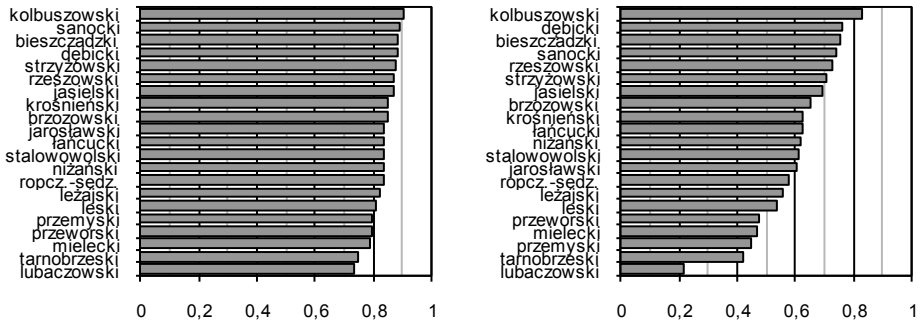
RESEARCH RESULTS

In order to obtain an accurate picture of the spatial differentiation of level of the information society development of in the podkarpackie voivodship, i.e. of the disparities which exist between its poviats, values of the core indicators were calculated on the basis of the collected data. Then, for each poviat, we computed the values of P (by the product method) and T (by the TOPSIS method) sub-indices corresponding to five aspects of the information society development. Obtained results are graphically presented in figures 1–5. In these figures we put two graphs: the left one shows the P values and the right one presents the T values.

The values presented in figures indicate that, for each pillar, poviats rankings created from the sub-indices P and T are very similar. This is also confirmed by the Spearman's rank-order correlation coefficients, which values range from 0,979 (readiness to function in the IS) to 0,994 (use of e-services). A comparison of poviats positions in the rankings that are based on sub-indices P and T shows that the greatest differences between positions in the rankings relate to poviats:

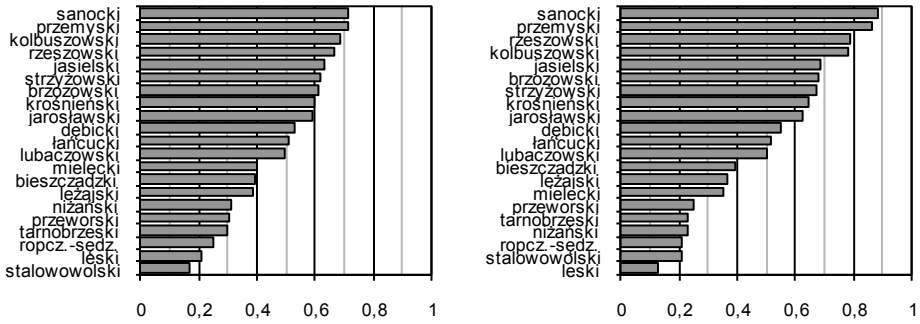
- readiness to function in the IS: jarosławski (3); niżański, przemyski and sanocki (2);
- use of computers: mielecki and niżański (2);
- use of the Internet: brzozowski and niżański (2);
- use of e-services: bieszczadzki and przemyski (2);
- use of e-government services: niżański (3), lubaczowski and przeworski (2).

Figure 1. Residents and households readiness for functioning in the information society (P1 and T1)



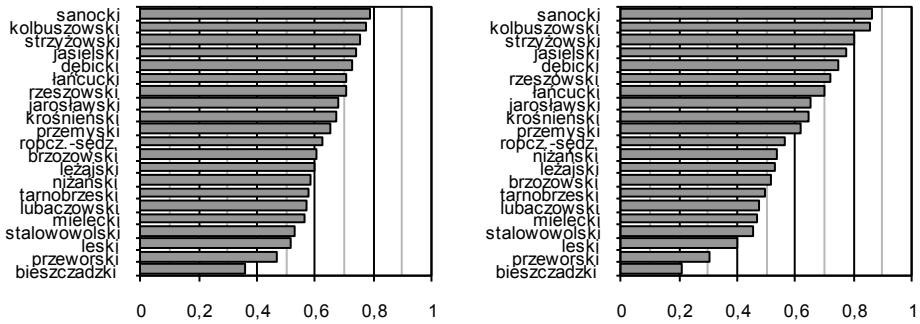
Source: own elaboration based on surveys

Figure 2. Scope of use of computers by residents (P2 and T2)



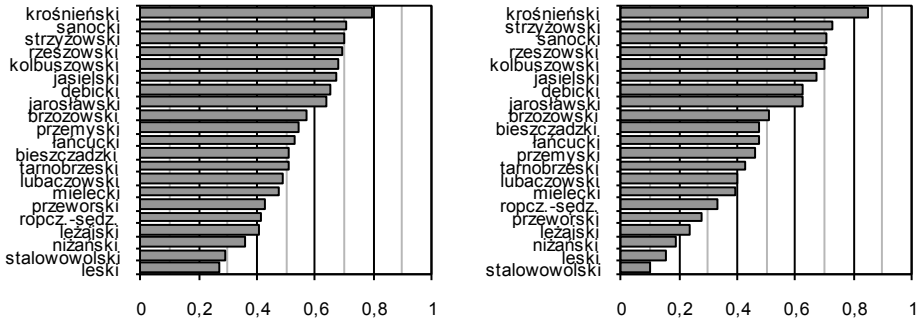
Source: own elaboration based on surveys

Figure 3. Scope of the Internet use by residents (P3 and T3)



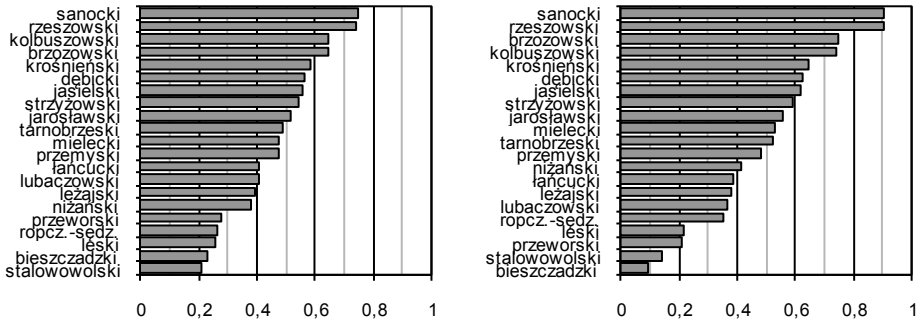
Source: own elaboration based on surveys

Figure 4. Scope of use of e-services offered in the Internet by residents (P4 and T4)



Source: own elaboration based on surveys

Figure 5. Scope of use of e-government services by residents (P5 and T5)



Source: own elaboration based on surveys

Analysis of results, given in figures, shows that the range of variation and differentiation of T sub-indices are greater than of sub-indices P. Coefficients of variation of sub-indices corresponding to aspects of IS development are as follows:

- readiness to function in the IS: for P1 – 5% and for T1 – 23%;
- use of computers: for P2 – 36% and for T2 – 46%;
- use of the Internet: the P3 – 17% and for T3 – 29%;
- use of e-services: for P4 – 26% and for T4 – 43%;
- use of e-government services: for P5 – 34% and for the T5 – 45%.

Sub-indices refer to different aspects of the information society. Therefore, we decided to see how strong correlations exist between their values. The values of Pearson correlation coefficients between sub-indices allow us to draw the following conclusions:

- Sub-indices determined by the multiplicative method: The least correlated with the other sub-indices is P1 (readiness to function in the IS), and the most – sub-indices P3 (use of the Internet) and P4 (use of e-services). At the same time the strongest relationships exist between P2 (use of computers) and P4 – 0,88 and P5 (use of the e-government services) – 0,87, the weakest – between P1 and P5 – 0,46 and P2 – 0,46.
- Sub-indices determined by the TOPSIS method: Also the least correlated with the other sub-indices is T1 (readiness to function in the IS), and the most – sub-indices T3 (use of the Internet) and T4 (use of e-services). At the same time the strongest relationships exist between T2 (use of computers) and T4 – 0,83 and between T3 and T5 (use of e-government services) – 0,80 and the weakest – between T1 and T5 – 0,45 and T2 – 0,46.

From figures it can be seen, that poviats occupy different positions in the rankings based on various sub-indices. High positions in the rankings created on the basis of sub-indices P and T are occupied by poviats: sanocki,

kolbuszowski, rzeszowski, strzyżowski, jasielski. Low places in P rankings are usually occupied by the poviats: leski, stalowowolski, przeworski, ropczycko-sędziszowski, niżański and in T rankings – by poviats: leski, stalowowolski, przeworski, lubaczowski, ropczycko-sędziszowski. Differences between positions occupied in P rankings by poviats: sanocki, jarosławski, jasielski, kolbuszowski, przeworski and in T rankings poviats: jasielski, sanocki, rzeszowski, kolbuszowski, przeworski – are relatively small. Simultaneously, the most diversified in the P rankings are positions occupied by poviats: bieszczadzki, przemyski, tarnobrzeski, stalowowolski, lubaczowski, and in T rankings – poviats: bieszczadzki, przemyski, brzozowski, niżański, stalowowolski.

To obtain an overall assessment of the level of IS development in poviats of the podkarpackie voivodeship, sub-indices corresponding to the aspects of IS development were aggregated into two composite indices IP and IT. IP and IT values were calculated on the basis of sub-indices P and T as the weighted geometric mean with the weights determined by the method of AHP. Similarly as rankings established on the basis of sub-indices, rankings of poviats created from the indices IP and IT are alike, value of the Spearman's rank-order correlation coefficient is equal to 0,98.

Analysis of IP and IT values shows that the range of variation and differentiation of index IT are greater than of index IP, the coefficients of variation are equal to 39% and 25% for index IT and IP respectively. A comparison of poviats positions in the rankings that are based on indices IP and IT shows that the greatest differences between positions in the rankings relate to poviats: ropczycko-sędziszowski (3), kolbuszowski, krośnieński and leżajski (2).

Table 2. Poviats classifications based on the indices IP and IT

Developmental stage	IP	IT
High ($> \bar{I} + s$)	sanocki, krośnieński, rzeszowski, kolbuszowski	sanocki, kolbuszowski, rzeszowski, krośnieński, strzyżowski
Higher than average ($\bar{I} < I \leq \bar{I} + s$)	strzyżowski, jasielski, dębicki, jarosławski, brzozowski, przemyski, łańcucki	jasielski, dębicki, jarosławski, brzozowski, przemyski, łańcucki
Lower than average ($\bar{I} - s < I \leq \bar{I}$)	lubaczowski, mielecki, tarnobrzeski, leżajski, bieszczadzki	mielecki, lubaczowski, tarnobrzeski, bieszczadzki, ropczycko-sędziszowski, leżajski
Low ($I \leq \bar{I} - s$)	przeworski, niżański, ropczycko-sędziszowski, leski, stalowowolski	przeworski, niżański, leski, stalowowolski

Source: own elaboration based on surveys

The values of the indices IP and IT were used to determine the groups of poviats with similar levels of IS development. To determine the limits of the classes we used the arithmetic mean ($\bar{I}$) and standard deviation (s) of indices IP and IT. Table 2 shows received poviats classification.

The results in table 2 indicate that selected groups of poviats do not form distinct clusters on map of the podkarpackie voivodeship (e.g. sanocki and rzeszowski, leski and stalowowolski). There is no center-periphery differentiation, it is sufficient to compare the positions of the two poviats: rzeszowski and sanocki. Also the location of the poviat close to large urban centers (urban poviats) do not always contribute to a high level of IS development in its area (e.g. tarnobrzeski and przemyski).

CONCLUDING REMARKS

No satisfactory and widely accepted definition of information society and the rapid development of information and communication technologies and their increasingly wide applications cause that the substantive meaning of some of the core indicators may change as time goes. Therefore the core indicators, used in this study, were selected so as to concern all stages in the model of ICT development process towards the information society and to be appropriate for measuring and comparing the level of the SI development in territorial units such as LAU1 (NUTS4) now and in the coming years.

The results of the research show that poviats rankings based on indices obtained by the product method and the TOPSIS method are very similar. There is no center-periphery differentiation in the IS development in podkarpackie voivodship and the location of poviat close to large urban centers do not affect the level of IS development in its area.

Having a knowledge of spatial differences and similarities between the IS development in territorial units, allows a more rational allocation resources to support development of the IS and the e-economy. Valuable conclusions can be drawn from the separate analyzes of sub-indices (lower level composite indices) and the relationships between them. Among other things, it is possible to identify the strengths and the weaknesses of each territorial unit in the IS development.

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