MULTIPARAMETER ASSESSMENT OF THE WEST POMERANIAN REGION IN TERMS OF THE ICT USE

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Summary

The aim of the article is to assess the position of the West Pomeranian province in the ranking of the Polish provinces due to the use of the information and communication technologies in enterprises. This study used the method of the multi-criteria decision support Analytic Network Process (ANP) and the expert knowledge was taken into account, as well as the preferences of the decision-maker expressed using the network structure of criteria, evaluations and assessments.

Keywords: information and communication technologies, analytic network process, ranking

Introduction

Modern companies, in order to succeed in the local market, and above all in the global market, should skilfully use the achievements of the information and communication technologies (ICT) in their activity. The Central Statistical Office (CSO) of Poland defines ICT as the family of technologies for processing, gathering and transmitting information electronically [8, p. 17]. That is why an important role, as the business tool, is played by: the Internet, mobile phones and electronic media (e.g. radio, satellite TV). Modern systems for transferring information and devices, which increase the speed of its flow allow the companies to: quickly reach a wider audience, reduce operating costs and make secure financial settlements.

According to Katarzyna Witkowska (president of the ICT cluster West Pomerania), the market of information technology (IT) is the fastest growing industry in Western Pomerania, and the IT specialists cannot complain about the difficulties in finding a job [3]. Members of the ICT cluster conduct the activity, which belongs to the computer industry: software, multimedia, telecommunication networks and IT outsourcing. Thanks to this they establish business contacts, gain knowledge and undertake cooperation [3].

The aim of the article is to assess the position of the West Pomeranian province in the ranking of Polish provinces based on the level of the use of ICT technologies in enterprises, in 2015. The experiment has used the method of multi-criteria decision support Analytic Network Process (ANP), which allowed the arrangement of Polish provinces taking into account the expertise and preferences of the decision-maker expressed using the network structure of criteria, scales and assessments. The obtained results were used to analyse the system of ICT in the economic life of Polish entities.

1. The method of multi-criteria decision support ANP

The structure of the decision problem in the ANP method [6] [7] is presented as a network, which is a system of components important for the problem in question. The network can be expanded by introducing the relationships between: the groups of elements and inside them and feedback. The quality of connections depends on the defined degree of the mutual impact of the elements of individual components. ANP is the extension of Analytic Hierarchy Process (AHP) [4] [5], that are why the networks can be created from the hierarchy as a result of the gradual increase in the
number of hierarchical connections. While the pair comparisons are made in reference to all combi-
nations of mutual connections between the elements and their groups [1, p. 9–10].

The aim of ANP is to assign each decision-making variant with the standardised final assess-
ment (set in the scale vector), which can be interpreted as the utility of the i-th variant. The scale
vector is obtained based on the comparisons between pairs of the criteria and decision-making var-
iants due to the additional criteria. These operations are performed using the nine-point Saaty
scale [10, p. 70], by assigning the individual comparisons with the numerical assessment and the
verbal description. The priority vectors are presented in the form of matrices of standardised assess-
ments and introduced to the appropriate columns, so-called super matrices of the decision-making
network. It presents the priorities indicating the impact of the component elements on other system
elements. The resulting vector magnitudes of the scale of the decision-making problem in question
allow ranking the decision-making variants and the selection of the best variant for the decision
maker [10, p. 66]. The computational process of the ANP method takes place in several steps [11].

1) Grouping criteria and decision variants into components (source, output or indirect) and con-
necting them using link paths.

2) Creation of dependent networks (external and internal), which can be presented in the form of
zero-one matrix.

3) Comparison of pairs of components and determination of the matrix of their weights – V.
For this purpose, a nine-point Saaty scale is used [1, p. 16] and the partial scale vectors are
obtained. This stage is an essential part of the AHP method, and its detailed description can be
found, among others, in the work by T. Trzaskalik [10, p. 69].

4) As a result, the pair comparisons of the network elements the initial super matrix Ω is obtained.
It is assumed that the model consists of N components marked as C₁, C₂, ..., Cᵢ, ..., Cᵢ, i-th com-
ponent consists of nᵢ elements – eᵢ₁, eᵢ₂, ..., eᵢₙᵢ, while the number of components can be differ-
ent. As a result of pair comparisons of the i-th component in terms of elements of the j-th com-
ponent, the partial scale vectors are obtained, which create the matrix block Ω (discussion of
the general form of the decision super matrix Ω is presented in: [1, p. 14], [11, p. 67]):

Ω =
| Ω₁₁  Ω₁₂  ...  Ω₁N |
| Ω₂₁  Ω₂₂  ...  Ω₂N |
| ...  ...  ...  ... |
| Ω_N₁  Ω_N₂  ...  Ω_NN | (1)

written as Ωᵢⱼ:

Ωᵢⱼ =
| ωᵢ₁j  ωᵢ₂j  ...  ωᵢNj |
| ωᵢ₁j  ωᵢ₂j  ...  ωᵢNj |
| ...  ...  ...  ... |
| ωᵢ₁₁  ωᵢ₁₂  ...  ωᵢ₁nj | (2)

where: ωᵢhᵢ – the dependence of the h-th element from the i-th component with the l-th element
of the j-th component, in the network of connections; if ωᵢhᵢ = 0 then there is no direct impact
between the given elements.
5) Creation of the super matrix weighed by multiplying the initial super matrix blocks and their corresponding component weights. The component weight matrix $V$ with dimensions $N \times N$ takes on the form:

$$V = \begin{bmatrix}
V_{11} & V_{12} & \cdots & V_{1N} \\
V_{21} & V_{22} & \cdots & V_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
V_{N1} & V_{N2} & \cdots & V_{NN}
\end{bmatrix} \quad (3)$$

The weighted super matrix can be written as:

$$\Omega = \Omega \cdot V \quad (4)$$

The resulting matrix is the stochastic matrix, which all columns add up to unity – it can be obtained also by standardising the columns of the weighted matrix.

6) Determination of the super matrix of border values, which takes into account all dependencies, and has the form:

$$\lim_{n \to \infty} \Omega^k = G \quad (5)$$

Raising the weighted super matrix to the power allows capturing all significant relationships. The columns of matrix $G$ are identical and add up to one. Using the border super matrix $G$, it is possible to obtain the scale vector for decision-making variants. The complete scale vector represents the assessments of each element of the model due to the remaining network components. Therefore, we should select those elements from matrix $G$, which correspond to the analysed variants.

7) Conversion of the resulting variant assessments by vector standardisation of the variant assessment vector or conversion of the assessment vector in relation to the weight of the best variant or another arbitrarily selected reference point.

8) The synthesis of results, in the form of supplementing the stages 1–7, from the subsystems (different networks).

2. The use of the selected ICT technologies in enterprises

The empirical material, which was used in the studies on the analysis of the position of the West Pomeranian province in the national ranking of provinces in terms of ICT usage in enterprises came from the CSO of Poland. This was the information from 2015, which had its source in SSI-01 forms – designed for companies outside the financial sector [9].

Entities, which were included to the representative sample – 18.8 thousand companies – accounted for slightly more than 18% of the entire population. The SSI-01 report was submitted by slightly more than 14 thousand companies (about 75% companies), in which the number of employees was at least 10. The activity conducted by the companies was classified according to the Polish Classification of Activities (PKD) to the following sections: C, D, E, F, G, H, I, J, L, M, N, S [8, p. 62]. Small companies dominated (58.5% of the total), the percentage of the medium-sized enterprises amounted to 20.6%, while the percentage of large companies accounted for 20.9%.

According to CSO in 2015 [8, p. 17] 94% of companies used computers in their business. The highest percentage of companies was noted in the Lower Silesian province (97.4%), and the lowest in the West Pomeranian province (89.3%). Generally, 92.7% entities had access to the Internet. Most
often they used the broadband connections (91.9%), while the mobile broadband connections were used by 61.5% companies. The lowest percentage was observed in the West Pomeranian province (86.7%) and Warmia and Masuria (89.8%), the highest one in the Lower Silesia (95.7%) and Pomerania (94.9%). Enterprises of the West Pomerania province recorded a low note among entities from other regions in terms of having their own website. The website was most often used in West Pomerania in order to present the products, catalogues or price lists, or services, while the least often used functions included the personalisation of the website content for frequent and regular users. However, the West Pomeranian region was the weakest in case of using the social media in their activity and in contacts with public administration (e-administration), although this form of communication saves time and financial resources. The computational cloud services were used by a small percentage of companies (7.3%). While the ERP systems (for planning and managing the company resources) or CRM (for managing information about the clients) were used, respectively, by every fifth and fourth company (usually large). Only 12.6% companies had the formally defined security policy – over 50% of them were large entities.

3. Multi-criteria optimisation in the utility assessment

To carry out the analysis of the West Pomeranian province in terms of advancement of the ICT technology the ranking of Polish provinces was used. The arrangement of 16 provinces due to the use of ICT by enterprises in 2015 was obtained thanks to the Microsoft Excel spreadsheet and the Statistica 12 and Super Decisions programs.

At the beginning, the set of decision variants was defined, which included sixteen elements (provinces) evaluated due to four main measurable main criteria, which included specific measurable assessment criteria (sub-criteria).

1) ICT infrastructure (K₁):
   - remote access via the Internet to e-mail, documents or applications (K₁₁),
   - access to the Internet via broadband connection (K₁₂),
   - the use of ERP or CRM software packages (K₁₃),
   - purchase of services in the computational cloud (K₁₄),
   - formally defined information security policy (K₁₅).

2) Outsourcing (K₂):
   - maintenance of ICT infrastructure (K₂₁),
   - support for office software (K₂₂),
   - support for software/systems of business management (K₂₃),
   - support for Web type of solutions (K₂₄),
   - ensuring security and data protection (K₂₅).

3) Functions of Internet services (K₃):
   - the usage of privacy policy (K₃₁),
   - presentation of products, goods or services and price lists (K₃₂),
   - checking the status of order implementation on-line (K₃₃),
   - enabling the ordering of products according to own specification (K₃₄),
   - personalisation of the website content for frequent/regular users (K₃₅),
   - sending electronic invoices (K₃₆),
   - conducting e-sales through the website or mobile applications (K₃₇).
4) Electronic data exchange with entities (K₄):
   - use of social media (K₄₁),
   - use of the Internet in contacts with public administration (K₄₂),
   - receiving electronic invoices (K₄₃),
   - e-shopping through the website, mobile applications or EDI type of messages (K₄₁).

Figure 1. Grouping results with the k-means method

Source: own study.

The essential calculations to address the solution of the decision-making problem presented in the article preceded the auxiliary studies, which involve the performance of the classification of Polish provinces. Fig. 1 presents the result map of regional grouping due to the involvement of companies in ICT obtained with the k-means method [2]. The experiment enabled the creation of preference profiles for the groups of provinces. As a result of using the Statistica 12 program 3 classes of provinces were obtained due to the diversity of entity involvement in the ICT use, in 2015. The first group included the areas with entities, which stood out with the highest saturation of ICT technologies, in the second group this level was average, and in the third group the lowest. An example preference disproportion (obtained scale vectors) for individual profiles of decision variants, which include the potential of individual regions is presented in fig. 2.
In the preliminary test, the main criteria were compared to the pairs from the point of view of each group of provinces. Their continuation was the performance of pair comparisons of sub-criteria inside each network component. The result of these actions was the partial scale vectors, which created the weight matrix. The object assessment matrix was the last element of the super matrix, in which the scale vectors were determined on the rule of linear transformation of empirical data. The statement of individual partial matrices enabled the receipt of the initial value of the super matrix. With the assumption that components are indistinguishable, the received matrix was the weighted super matrix. The aim of the next stage of research was to determine the border matrix, and its elements formed the scale vector, which corresponded to the analysed decision variants. After standardisation, this vector was used for creating the ranking of provinces according to the degree of ICT use by companies in 2015. Calculations using the ANP method were performed in the Super Decisions program.

Table 1 presents the ranking of Polish provinces. Each column included: quotations determined in relation to the best result (ideal), final scale vector (normalised values), fragment of the super matrix (RAW). The position of individual provinces was impacted by the value of the normalised final assessment.

The West Pomerania region was on the 11th place of the ranking. Therefore, its location was pretty far compared to the leader, which in 2015 was the Masovia region. That’s why, actions of the companies concentrated in this region should follow the companies from provinces: Masovia, Opole, Lower Silesia or Silesia, which can appropriately use the ICT in their field by, e.g., investing in modern equipment and software, conducting the activity based on the digital economy, communication with partners using the network, using social media in order to acquire new customers and suppliers.
Table 1. Ranking of provinces in terms of the ICT use in 2015

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of province</th>
<th>Ideals</th>
<th>Normals-$b_1$</th>
<th>Raw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mazowieckie</td>
<td>1,00000</td>
<td>0,07663</td>
<td>0,02555</td>
</tr>
<tr>
<td>2</td>
<td>Opolskie</td>
<td>0,87140</td>
<td>0,06678</td>
<td>0,02226</td>
</tr>
<tr>
<td>3</td>
<td>Dolnośląskie</td>
<td>0,86700</td>
<td>0,06644</td>
<td>0,02215</td>
</tr>
<tr>
<td>4</td>
<td>Śląskie</td>
<td>0,86313</td>
<td>0,06615</td>
<td>0,02205</td>
</tr>
<tr>
<td>5</td>
<td>Wielkopolskie</td>
<td>0,84330</td>
<td>0,06463</td>
<td>0,02154</td>
</tr>
<tr>
<td>6</td>
<td>Pomorskie</td>
<td>0,83958</td>
<td>0,06434</td>
<td>0,02145</td>
</tr>
<tr>
<td>7</td>
<td>Łódzkie</td>
<td>0,82244</td>
<td>0,06303</td>
<td>0,02101</td>
</tr>
<tr>
<td>8</td>
<td>Małopolskie</td>
<td>0,81859</td>
<td>0,06273</td>
<td>0,02091</td>
</tr>
<tr>
<td>9</td>
<td>Podlaskie</td>
<td>0,80987</td>
<td>0,06206</td>
<td>0,02069</td>
</tr>
<tr>
<td>10</td>
<td>Kujawsko-pomorskie</td>
<td>0,80819</td>
<td>0,06194</td>
<td>0,02065</td>
</tr>
<tr>
<td>11</td>
<td>Zachodniopomorskie</td>
<td>0,77705</td>
<td>0,05955</td>
<td>0,01985</td>
</tr>
<tr>
<td>12</td>
<td>Lubelskie</td>
<td>0,77504</td>
<td>0,05939</td>
<td>0,01980</td>
</tr>
<tr>
<td>13</td>
<td>Podkarpackie</td>
<td>0,77084</td>
<td>0,05907</td>
<td>0,01969</td>
</tr>
<tr>
<td>14</td>
<td>Lubuskie</td>
<td>0,74780</td>
<td>0,05731</td>
<td>0,01910</td>
</tr>
<tr>
<td>15</td>
<td>Warmińsko-mazurskie</td>
<td>0,73636</td>
<td>0,05643</td>
<td>0,01881</td>
</tr>
<tr>
<td>16</td>
<td>Świętokrzyskie</td>
<td>0,69852</td>
<td>0,05353</td>
<td>0,01784</td>
</tr>
</tbody>
</table>

Source: own study based on CSO data.

The position of the West Pomeranian province is not surprising, if we trace the amount of gross expenditure on ICT per 1 company. In 2014, in West Pomerania province, these expenses amounted to 16.89 thousand PLN and this was one of the lowest amounts spend in ICT. For comparison, the leader of the ranking, that is the Masovia province, noted the expenditures at the level of 199.31 thousand PLN [9]. These resources were usually spent on: information or telecommunications equipment, financial leasing of ICT devices and own development or modification of the purchased software.

4. Conclusions

The Masovia province was on the first place of the resulting ranking. It is this region, which in 2015 had the entities, which were characterised by the high level of saturation with IT equipment and could properly use the ICT technologies in the management process. On top of the ranking we can also find provinces: Opole, Lower Silesia and Silesia. Definitely distant placed from the leader went to the provinces: Lublin, Warmia and Masuria, and Świętokrzyskie. The West Pomeranian province was on the 11th position, distant from the top, but still high, if were look at the gross expenditures spent on ICT in this region. In 2014 the expenditures on ICT were ones of the lowest in Poland. Only the Świętokrzyskie province devoted less resources for the ICT development – 12.24 thousand PLN per company.

In the article, the fundamental calculations were conducted by using the ANP method. This allowed for the inclusion of the preferences of various objects in the form of network relations. The
study assumed the existence of three preference profiles. It should be noted that if the provinces were assessed from the point of view of preferences of only one profile, for example the first one (with strongly developed IT infrastructure), then the results of the ranking would be detrimental for the provinces related to the other profiles. Especially with the third one, where the IT infrastructure is modest (underfunded), and the Internet technologies and outsourcing of IT services are the main determinant of the advancement of companies in these regions.

Although the network models allow capturing the relationships between individual elements of the model (internal, external, feedback, cycles) in a natural way, their construction requires adequate knowledge and experience of the analyst.

Bibliography

[1] Adamus W., Gręda A., Wspomaganie decyzji wielokryterialnych w rozwiązywaniu wybry-
nych problemów organizacyjnych i menedżerskich, „Badania operacyjne i Decyzje”, nr 2, 2005.
[3] IT specialists grow (in Polish). Information service „Szczebin Biznes” (http://szcze-
cinbiznes.pl/informacje/Informatycy-rosna_3160, Internet resources of 12.10.2016).
tematyczne/nauka-i-technika-społeczeństwo-informacyjne/spoleczenstwo-informacyjne/, Internet resources of 01.09.2016).
WIELOPARAMETRYCZNA OCENA WOJEWÓDZTWA ZACHODNIOMORSKIEGO POD WZGLĘDEM WYKORZYSTANIA ICT

Streszczenie

Celem artykułu jest ocena pozycji województwa zachodniopomorskiego w rankingu województw Polski ze względu na wykorzystanie technologii informacyjno-telekomunikacyjnych w przedsiębiorstwach. W badaniach wykorzystano metodę wielokryterialnego wspomagania decyzji ANP oraz uwzględniono wiedzę ekspertów i preferencje decydenta wyrażone za pomocą sieciowej struktury kryteriów, wag i ocen.

Słowa kluczowe: technologie informacyjne i komunikacyjne, analityczny proces sieciowy, ranking

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