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Multi-criteria assessment of ICT development in public administration in Poland

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Abstract: Information and communications technology (ICT) has become a stimulus for socioeconomic change and created new prospects for the development of e-government, thereby ushering in a new era in the provision of public services. With the development of ICTs, new ways of delivering public services are increasingly popular, and new opportunities that offer a chance to improve the professional position of public officials are emerging. Therefore, the main aim of this study is to assess the development of ICT technologies in state and local government entities in Poland. A review of the literature on the subject using the triangulation method allowed one to bring closer the considerations on the development of e-government services in Poland and the world, and the implementation of ICT tools in public administration entities. Based on an index analysis, the access of public administration entities and their employees to the Internet and ICTs and the development of public services provided electronically were assessed. The results of the study showed that the COVID-19 pandemic has accelerated changes in access to e-government services and the growth of remote work. It has highlighted the need to equip workers and train them properly. The analysis of the EGDI index places Poland in 34th place among UN countries in 2022. Concerning EU countries, Poland was ranked 17th for OSI and 16th for HCI and TII. In turn, our research using multicriteria analysis methods allows us to conclude that public administration activities in Poland should be directed at local units. The use of linear ordering measures in the research (TOPSIS, VIKOR, and Hellwig) allowed us to establish a ranking of individual levels of public administration in Poland for the development of ICT technologies. The leader in the ranking according to all three methods is the marshal offices. The last position in the ranking according to the VIKOR method is shown by municipal offices, according to the TOPSIS and Hellwig methods, they are in the penultimate position.
Keywords: ICT; TOPSIS; Hellwig, VIKOR, public administration units, Poland

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Introduction

The development of all spheres of economic life is inextricably linked to information and communications technologies, which provide a fast, flexible, and efficient way to transform information. This is very important in terms of the development of public services because fast access to public services and flexible time for filling out official documents not only reduce the waiting time for dealing with an issue in the office, but also have a positive effect on increasing the competence of officials because training in ICT technology improves their professional skills.
Among other things, Walencik (2018) points out that the increasing participation of ICTs in everyday life and public expectations for easier and faster dealing with official matters have given rise to the development of new solutions by public institutions. The author also stressed that citizens and representatives of business are even demanding that government activities be more transparent and ensure the delivery of services more quickly and efficiently.
Public administration is undergoing a noticeable digital transformation in the world, but also in Poland, which demonstrates the innovativeness of public entities (including local governments), and is also a way to improve transparency of operations and create public value (Gil-Garcia et al., 2018). The digital transformation of public administration entities is aimed at achieving the desired degree of technological advances, targeting the transformations taking place in public entities regarding services, resources, processes, organisational culture, and competencies, and using digital technologies (Androniceanu et al., 2023).
Quick access to public information, increased transparency of public administration activities, and readiness to adapt to citizens' needs are essential for an efficient, open, and responsive government (Rodríguez-Bolívar, 2014, p. 2). Therefore, the main aim of this study is to assess the development of ICT technologies in state and local government entities in Poland. The achievement of this research aim will be made possible by a review of the literature on the subject and an index analysis of the development of ICTs in public entities, with particular emphasis on e-government services. This analysis will use the multi-criteria linear ordering methods TOPSIS, VIKOR and Hellwig.

1. Literature review

Since the 1990s, the issue of e-government has become the subject of political discussions and scientific research. It was then that a large number of countries began to implement projects related to the development of such solutions. They placed particular emphasis on the use of ICTs to provide electronic information and services to citizens and business entities. At the same time, they sought to increase the

efficiency and responsiveness of the entities (Chen & Gant, 2001). Digital administration is crucial for more efficient, transparent, and effective management processes in meeting beneficiaries' requirements (Makki & Alqahtani, 2022).

The development of information and communication technologies has reached a level where their use in the management of public administration entities is becoming not only expedient, but also inevitable. The Internet and information and communications technologies have created a technical and technological foundation that can significantly improve the efficiency of public administration, provide stakeholders with access to information they need, simplify bureaucratic procedures, and reduce decision-making time (Derindag et al., 2019).

The term e-government has become understood and increasingly used by most citizens. The concept can be defined as a tool for providing public services and public information over the Internet in a more efficient and integrated way. The Internet services offered by government institutions or individual local government entities are popular among the public. The implementation of modern IT solutions is primarily aimed at improving the quality and efficiency of government operations (Dufva & Dufva, 2019; Mishchuk et al., 2023). This also involves developing new forms of communication between the government and citizens and improving the quality of life through economic and social development. It is particularly important to promote transparency, communication, and active citizen participation (Schwester, 2009). Research on the positive impact of ICT infrastructure investment on economic growth has been conducted by Khan & Majeed (2019) among others. Trajkovik (2011) formulated the basic four goals that can be achieved if e-government solutions are properly implemented: 1) government services available online, 2) computerised administration, 3) knowledge-based administration, and 4) transparency in administration.

Digital government (DG) is also of great interest to researchers, along with the topic of e-government. An analysis of the literature on the subject was undertaken by Scholl (2009, 2014, 2015, 2016), among others, in an attempt to identify the scientists who form the core of the DG research community, located mainly in Europe, North America, and Asia. Furthermore, Erman and Todorovski (2009), using social network analysis, identified the most frequently discussed topics in scientific publications in the field of (1) advanced DG research, (2) integration of electronic services (e-services) in public administration, (3) the digital divide, (4) success and failure factors of DG projects, and (5) action plans for future research.

Other studies have dealt with index analysis of e-government. Griffin and Halpin (2005) indicated that the areas on which the analysis should focus include phases of e-government development, access to electronic services via the Internet, stakeholder involvement, and the costs and benefits of e-government. However, data in this regard is not always available. To properly evaluate the effectiveness of electronic public services, research should be conducted from the perspective of both users and the public administration (Androniceanu & Georgescu, 2023). However, measuring this phenomenon and comparing it is problematic (Walencik, 2018). Nabafu & Maiga (2012) argued that there is a severe shortage of information on the

implementation of e-government at the local level, among others, as most of the current research in this area focuses on the central government. Research on the positive impact of the implementation of knowledge-based technologies and ICT infrastructure and software on organisational performance in local governments was carried out by Farmansyah and Isnalita (2021), among others.
Therefore, the authors of this study see a research gap in determining the level of e-government development based on synthetic measures (TOPSIS, VIOKR, and HELLWIG) at the level of state government and self-government administration: municipal, district, and marshal offices in Poland.
In conclusion, a review of the studies and literature on the subject allowed for the formulation of the following research questions: 1) How is the scope of e-government services developing in Poland? How do individual levels of public administration in Poland rank in the e-government development ranking according to synthetic indicators measured using the TOPSIS, VIKOR, and Hellwig methods?

2. Materials and methods

The study used a triangulation method, with its main purpose being to critically analyse the literature on the development of e-government services and ICT technologies that enable both households and businesses to access high-speed data transfer and efficient delivery of public services. Triangulation of data sources occurs when different independent sources are used. Therefore, literature from databases was analysed. A literature survey was conducted using intelligent tools for tracking and analysing scientific results, among others, Zotero, software that allows automatic retrieval of bibliographic data and full texts from online library catalogs and discussion of research results.
The empirical part of the work includes, first, an assessment of the EGDI (E-Government Development Index) based on the 2022 United Nations report on e-government presenting digital government research in all 193 member states (https://publicadministration.un.org/egovkb/en-us/). Against the background of the assessment of e-government in the world with data compiled for Poland, the second part includes own research on the multi-criteria assessment of individual types of public administration (central and local government) in Poland in 2020-2022 based on the Central Statistical Office data on the use of ICT resources.
In the empirical part of the study, based on the data published by Statistics Poland, the study attempted to make an index analysis of the use of ICT resources by public administration entities in 2017-2021. Among other things, the analysis concerned the access of the entities to the Internet and ICT equipment, in particular the employees' mobile devices, the IT service in public entities, ICT training, open data policy and strategy, and the electronic services provided. The analysis is intended to provide an overview of the process of development of ICT services and tools by government and local government entities in Poland.

In this article, the use of information and communication technologies in public administration units is discussed using the TOPSIS, VIKOR, and Helwig linear ordering methods. Assessments of the method of implementing ICT in public administration units are discussed based on indicators developed by the Central Statistical Office for the years 2020-2022. A total of 19 indicators were subjected to preliminary analysis. The variables that were the basis for the collective assessment using linear ordering methods are presented in Figure 1.

Figure 1. Indicators of ICT use in public administration units in Poland

STIMULANTS	DESTIMULANTS	INDICATORS REJECTED
• x_3 - providing ICT training to employees; • x_5 - using electronic document management as the basic method of documenting the course of handling and resolving cases; • x_7 - having an implemented ISO system; • x_8 - using Business Intelligence tools; • x_9 - providing applications that can be downloaded to mobile devices offering e-services; • x_{10} - using numerical maps; • x_{11} - supporting the development of digital skills among citizens; • x_{14} - using cloud computing services; • x_{18} - making spatial data available to citizens; • x_{19} - enabling citizens to participate in online voting and social consultations on matters within the individual's competence;	• x_1 - employees equipped with mobile devices with Internet access; • x_2 - having internet; • x_6 - having a policy or strategy for sharing open public data; • x_{13} - having a website in a foreign language version; • x_{17} - using their own electronic inbox solutions;	• x_4 - using electronic document management; • x_{12} - having a website adapted to be operated by mobile devices; • x_{15} - providing services to citizens via the Internet; • x_{16} - using an electronic inbox on the Electronic Platform of Public Administration Services (ePUAP) platform;

Source: study based on: https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/spoleczenstwo-informacyjne/spoleczenstwo-informacyjne-w-polsce-w-2023-roku,1,17.html (10.04.2024).

The coefficient of variation was calculated to verify the selected indicators. At this stage of the analysis, indicators x_4; x_{12}; x_{15}, and x_{16} were excluded due to the low value of their coefficient of variation, which was below 10%. The study compared 3 linear ordering methods. The individual steps of the TOPSIS, VIKOR, and Hellwig methods are presented in Table 1. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), a linear ordering method, enables the construction of a ranking that contributes to determining the ideal and anti-ideal solution of the so-called reference points thanks to a finite set of points (Onat et al., 2016). Its classic version is based on a decision matrix. The TOPSIS method allows for the comparison of many different factors and, consequently, for making the best choice,

with the variant closest to the positive solution, i.e., the pattern (PIS - Positive Ideal Solution), being considered optimal.

Table 1. Steps of the TOPSIS, VIKOR and Hellwig method

TOPSIS	HELLWIG	VIKOR
Step 1. Determination of the weight vector and calculation of the normalised matrix: $w = \frac{v}{\sum_k^n v}$; $\sum w=[w_1+w_2+...w_n]=1$ $\overline{x}_{ij} = \frac{X_{ij}-minX_{ij}}{maxX_{ij}-minX_{ij}}$ for stimulants; $\overline{x}_{ij} = \frac{maxX_{ij}-X_{ij}}{maxX_{ij}-minX_{ij}}$ for destimulants;	***Step 1.*** Calculation of the normalised matrix: $\overline{x}_{ij} = \frac{X_{ij}-minX_{ij}}{maxX_{ij}-minX_{ij}}$ for stimulants; $\overline{x}_{ij} = \frac{maxX_{ij}-X_{ij}}{maxX_{ij}-minX_{ij}}$ for destimulants;	***Step 1.*** Determination of the weight vector and calculation of the normalised matrix: $w = \frac{v}{\sum_k^n v}$; $\sum w=[w_1+w_2+...w_n]=1$ $\overline{x}_{ij} = \frac{X_{ij}-minX_{ij}}{maxX_{ij}-minX_{ij}}$ for stimulants; $\overline{x}_{ij} = \frac{maxX_{ij}-X_{ij}}{maxX_{ij}-minX_{ij}}$ for destimulants;
Step 2. Calculation of a weighted normalised matrix: $v_j=\overline{x}_{ij} * w_j$	***Step 2.*** Determining the ideal value $z_{0j} = \begin{cases} max_i\{z_{ij}\} \\ min_i\{z_{ij}\} \end{cases}$	***Step 2.*** Calculation of a weighted normalised matrix: $v_j=\overline{x}_{ij} * w_j$
Step 3. Calculating the best (A_j^+) ideal value and the worst (A_j^-) ideal value: $A_j^+ = (v_1^+, v_2^+, \dots, v_n^+) = \{(max_i v_{ij} \mid j \in B), (min_i v_{ij} \mid j \in C)\}$ $A_j^- = (v_1^-, v_2^-, \dots, v_n^-) = \{(min_i v_{ij} \mid j \in B), (max_i v_{ij} \mid j \in C)\}$	***Step 3.*** Calculation of the Euclidean distance from the ideal value $d_{i0} = \sqrt{\sum_{j=1}^{m}(z_{ij} - z_{0j})^2}$	***Step 3.*** Calculating the Utility Measure (Si) values: $S_i = \sum_{j=1}^{n} v_j$
Step 4. Calculation of the Euclidean distance from the ideal value and anit-ideal value: $S_i^+ = \left[\sum_{j=1}^{m}(V_{ij} - V_j^+)^2\right]^{0.5}$ $S_i^- = \left[\sum_{j=1}^{n}(V_{ij} - V_j^-)^2\right]^{0.5}$	***Step 4.*** Calculation of the arithmetic value of the Euclidean distance of individual region from the ideal value: $\overline{d_0} = \frac{1}{n}\sum_{i=1}^{n} d_{i0}$	***Step 4.*** Calculating the Regret Measure (Ri) values: $R_i = maxj[v_j]$
Step 5. Calculation of the ranking coefficient determining the similarity to the ideal solution, where the most advantageous option is the variant with the highest value: $p_i = \frac{S_i^-}{S_i^+ + S_i^-}$	***Step 5.*** Calculation of the standard deviation of the Euclidean distance of region from the ideal value: $S_d = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(d_{i0} - \overline{d_0})^2}$	***Step 5.*** Determine the VIKOR index value (Qi): $Qi = \left(\frac{S_i - S_+}{S_- - S_+}\right)V + \left(\frac{R_i - R_+}{R_- - R_+}\right)(1-V)$
	Step 6. Calculation the critical distance of the region from the ideal value: $d_0 = \overline{d_0} + 2S_d$	

	Step 7. Calculation of the value of a synthetic indicator determining the similarity to the ideal solution, where the most advantageous option is the variant with the highest value: $$q_i = 1 - \frac{d_{i0}}{d_0}$$	
Where: w_n - weight of the budget indicator; v - coefficient of variation of a single indicator; x_{ij} - nominal value of the budget indicator; $\overline{x}_{ij}$ - value of the budget indicator of the normalised matrix; v_{ij} - value of the budget indicator of the weighted normalised matrix; w_n - weight of a single budget indicator; A_j^+ - ideal value; A_j^- - anti-ideal value; S_i^+ -euclidean distance from the ideal value; S_i^- -euclidean distance from the anti-ideal value; p_i - ranking coefficient value; x_{ij} - nominal value of the budget indicator; $\overline{x}_{ij}$ - value of the budget indicator of the normalised matrix; z_{0j} - ideal value (pattern); $max_i\{z_{ij}\}$ - for stimulant variables; $min_i\{z_{ij}\}$ - for destimulant variables; d_{i0} - distance of objects from the ideal value; z_{ij} - normalised variable; z_{0j} - ideal value (pattern); $\overline{d_0}$ - arithmetic value of the Euclidean distance of individual regions from the ideal value; d_{i0} - distance of objects from the ideal value; S_d - standard deviation of the Euclidean distance of individual region from the ideal value; d_0 - critical distance of the LGU from the ideal value; q_i - synthetic indicator determining the similarity to the ideal solution; **S-** = max S, **S +** = min S, **R-** = max R, **R +** = min R, **v** = 0.5;		

Source: own elaboration based on: Roszkowska, Wachowicz 2024; Onat et al., 2016; Bąk 2018; Mesran et al., 2019.

TOPSIS also enables the indication of the so-called anti-pattern, the worst negative solution (NIS - negative-ideal solution) (Gaspars-Wieloch, 2023). The literature on the subject, among multi-criteria methods, characterises the VIKOR method as a method similar to TOPSIS. According to Ahmed and Majidi (2018), VIKOR (Vlse Kriterijumska Optimizacija i Kompromisno Resenje) as a ranking method enables decision-making in situations where the analysed aspects are disproportionate and demonstrate the incompatibility of criteria. Based on reference points, the VIKOR method, referred to as the compromise method, allows for the construction of a multi-criteria ranking index. The developed ranking is based on the distance (closeness measure) concerning the solution considered to be the best. (Opricovic, Tzeng, 2007). In turn, the Hellwig method is also referred to as the optimal predictor selection method or the information capacity indicator method (Kajewska-Szkudlarek and Łyczko, 2021). It is generally used in the field of economic research, mainly in domestic publications, but its popularity has been systematically increasing over the years. The mentioned method allows for the ordering of analysed features based on their similarity to the ideal solution calculated using the Euclidean distance (Roszkowska, 2024).

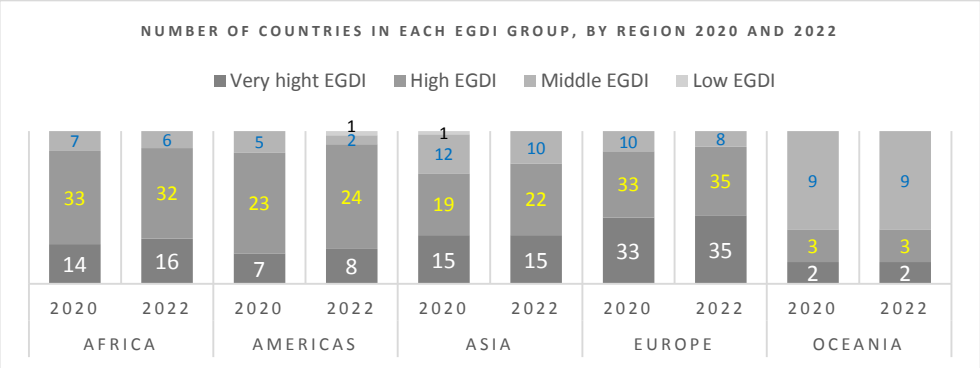
3. Results and discussion

3.1 Assessment of the EGDI indicator level – Poland against the background of UN and European countries

As emphasised by Walencik (2018), one of the methods of measuring e-government is the EGDI (EGDI (E-Government Development Index), an index developed by the UN in 2003, which is a weighted average of three indices: OSI (Online Service

Index); TII (Telecommunication Index); HCI (Human Capital Index). Figure 2 illustrates the development of the EGDI index in different regions of the world.
The highest level of the indicator, a very high EGDI in 2022 was characterised by 35 countries in Europe, 16 in Africa, 15 in Asia, 8 in the Americas, and 2 in Oceania. A very high EGDI rate in the analysed period was recorded by European countries - 58.3%, Asia - 25%, the Americas - 13.3%, and Oceania - 3.3%. On the other hand, the lowest level of the indicator – low EGDI was recorded by only one country in the Americas in 2022. Apart from Oceania, in all the examined regions of the world, the EGDI indicator escalated in 2022 compared to 2020, with the highest value recorded by countries in Europe (0.8305 in 2022). A similar level was shown by countries in the Americas (0.64381) and Asia (0.6493).

Figure 2. Number of countries in each EGDI group and EGDI average value, by region 2020 and 2022

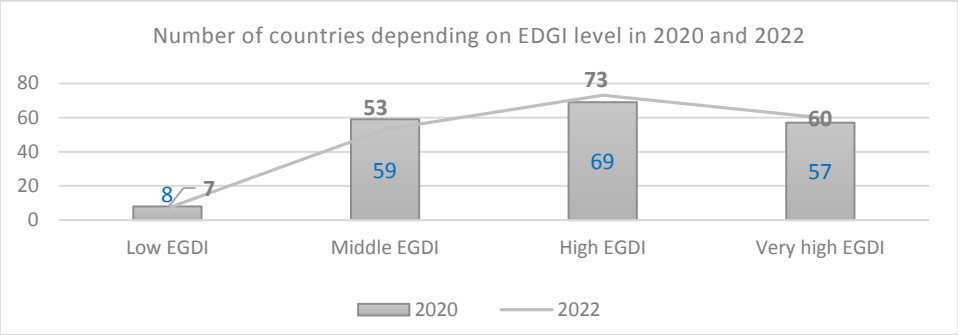


	EGDI average value 2020	EGDI average value 2022
Americas	0.6341	0.6438
Asia	0.6373	0.6493
Europe	0.817	0.8305
Oceania	0.5106	0.5081
193 Member States Africa	0.5988	0.6102

Source: own elaboration based on: 2020 and 2022 United Nations E-Government Surveys https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2022 '(15.07.2024).

In Europe, 19% of the countries have high EGDI values, and 81% have very high EGDI values. The proportion of countries in each group is increasing, indicating a steady improvement in e-government development in the region. Figure 3 shows the countries depending on EGDI levels in 2020 and 2022. The analysis of the presented data shows that the number of countries with high EGDI (from 69 to 73) and very high EGDI (from 57 to 60) increased, while the number of countries with middle EGDI (from 59 to 53) and low EGDI (from 8 to 7) decreased.

Figure 3. Number of countries depending on the EGDI level in 2020 and 2022



Source: own elaboration based on: 2020 and 2022 United Nations E-Government Surveys https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2022 '(15.06.2024).

In the aftermath of the COVID-19 pandemic, governments in all countries took action to deal with the crisis, although the scope and type of activities varied. According to UN data (), 90% of the activities in Europe focused on distance learning services, COVID-19 vaccinations, telehealth services, and medical check-up appointments. This was ca. 71% in Asia and both the Americas, 65% in Oceania and 40% in Africa. Table 2 presents the development of the EGDI index in Europe in 2018, 2020, and 2022, while Table 3 presents the values of the OSI, HCI, and TII indices in the EU countries.

Table 2. The level of the EGDI index in Europe according to the UN country ranking in 2018, 2020 and 2022

Country	EGDI 2022	EGDI 2020	EGDI 2018	EGDI Rank 2022	EGDI Rank 2020	EGDI Rank 2018
Denmark	0.9717	0.9758	0.915	1	1	1
Finland	0.9533	0.9452	0.8815	2	4	6
Sweden	0.941	0.9365	0.8882	5	6	5
Estonia	0.9393	0.9473	0.8486	8	3	16
Netherlands	0.9384	0.9228	0.8757	9	10	13
Malta	0.8943	0.8547	0.8011	15	22	30
Spain	0.8842	0.8801	0.8415	18	17	17
France	0.8832	0.8718	0.879	19	19	9
Austria	0.8801	0.8914	0.8301	20	15	20
Slovenia	0.8781	0.8546	0.7714	21	23	37
Germany	0.877	0.8524	0.8765	22	25	12
Lithuania	0.8745	0.8665	0.7534	24	20	40
Luxembourg	0.8675	0.8272	0.8334	26	33	18
Latvia	0.8599	0.7798	0.6996	29	49	57
Ireland	0.8567	0.8433	0.8287	30	27	22
Greece	0.8455	0.8021	0.7833	33	42	35

Country	EGDI 2022	EGDI 2020	EGDI 2018	EGDI Rank 2022	EGDI Rank 2020	EGDI Rank 2018
Poland	0.8437	0.8531	0.7926	34	24	33
Italy	0.8375	0.8231	0.8209	37	37	24
Portugal	0.8273	0.8255	0.8031	38	35	29
Belgium	0.8269	0.8047	0.808	39	41	27
Croatia	0.8106	0.7745	0.7018	44	51	55
Czech Republic	0.8088	0.8135	0.7084	45	39	92
Slovakia	0.8008	0.7817	0.7155	47	48	49
Hungary	0.7827	0.7745	0.7265	51	52	45
Bulgaria	0.7766	0.798	0.7177	52	44	47
Romania	0.7619	0.7605	0.6671	57	57	55
Cyprus	0.866	0.8731	0.7736	27	18	36

Source: own elaboration based on: 2018, 2020, and 2022 United Nations E-Government Surveys https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2022 (15.06.2024).

Studies in the EU show that Poland is characterised by an average level of development and quality of public services provided using electronic distribution channels. Based on the EGDI index, Poland is ranked 34th, with Denmark ranking first and Belarus - 58th. Based on the data contained in Table 2, it can also be pointed out that in the case of Poland, the EGDI index decreased from 0.8531 in 2020 to 0.8437 in 2022.

Table 3. The level of OSI, HCI, and TII indicators in EU countries in 2020 and 2022

Country	OSI- 2022		OSI- 2020		HCI- 2022		HCI- 2020		TII-2022		TII-2024	
	Value	Rank 2022	Value	Rank 2020	Value	Rank 2022	Value	Rank 2020	Value	Rank 2022	value	Rank 2020
Denmark	0.9797	3	0.9706	2	0.9559	5	0.9588	1	0.9795	1	0.9979	1
Finland	0.9833	2	0.9706	2	0.964	2	0.9549	2	0.9127	7	0.9101	6
Sweden	0.9002	5	0.9	6	0.9649	1	0.9471	5	0.958	3	0.9625	2
Estonia	1	1	0.9941	1	0.9231	12	0.9266	8	0.8949	9	0.9212	5
Netherlands	0.9026	4	0.9059	5	0.9506	6	0.9349	7	0.962	2	0.9276	3
Malta	0.8849	6	0.8118	15	0.8734	19	0.829	24	0.9245	6	0.9232	4
Spain	0.8559	11	0.8882	7	0.9072	14	0.8989	15	0.8895	11	0.8531	11
France	0.8768	8	0.8824	8	0.8784	18	0.8612	17	0.8944	10	0.8719	10
Austria	0.8827	7	0.9471	4	0.907	15	0.9032	12	0.8505	13	0.824	14
Slovenia	0.8666	9	0.8529	11	0.9439	8	0.9256	9	0.8239	20	0.7853	23
Germany	0.7905	18	0.7353	21	0.9446	7	0.9362	6	0.8957	8	0.8856	9
Lithuania	0.8347	12	0.8529	11	0.9251	11	0.9218	10	0.8636	12	0.8249	13
Luxembourg	0.8319	13	0.7647	18	0.8245	25	0.8097	26	0.9462	4	0.9072	7
Latvia	0.8135	14	0.5824	27	0.9284	10	0.9172	11	0.8378	15	0.8399	12
Ireland	0.7796	19	0.7706	16	0.9618	3	0.9494	4	0.8287	19	0.81	16
Greece	0.7753	21	0.7059	25	0.9405	9	0.8905	16	0.8206	21	0.81	16
Poland	0.7929	17	0.8588	10	0.9033	16	0.9001	14	0.8348	16	0.8005	19
Italy	0.8659	10	0.8294	14	0.8606	21	0.8466	19	0.786	25	0.7932	22
Portugal	0.7954	16	0.8353	13	0.8665	20	0.8463	20	0.8201	22	0.7948	21
Belgium	0.6899	25	0.6588	26	0.9614	4	0.9521	3	0.8294	18	0.8033	18
Croatia	0.8108	15	0.7529	19	0.85	22	0.8414	22	0.7711	26	0.7293	26
Czech Republic	0.6693	27	0.7235	22	0.9114	13	0.903	13	0.8456	14	0.814	15
Slovakia	0.726	23	0.7176	24	0.8436	23	0.8286	25	0.8328	17	0.7988	20
Hungary	0.7465	22	0.7471	20	0.8345	24	0.8509	18	0.7671	27	0.7255	27
Bulgaria	0.7092	24	0.7706	16	0.8221	26	0.8408	23	0.7984	23	0.7826	24
Romania	0.6814	26	0.7235	22	0.809	27	0.7995	27	0.7954	24	0.7586	25
Cyprus	0.7792	20	0.8706	9	0.8934	17	0.8429	21	0.9253	5	0.9057	8

Source: own elaboration based on: 2018, 2020, and 2022 United Nations E-Government Surveys https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2022 [15.06.2024].

Poland achieved the best, 24th position in the UN country ranking according to the EGDI index in 2020, in 2022 it dropped by as much as 10 places to 34th position in the ranking, thus approaching the result from 2018 (33rd position). When evaluating the level of development of e-government in EU countries, Table 3 compares the three main components of EGDI. A detailed analysis of the OSI (Online Service Index) indicator indicates that in 2022 the leader in the ranking was Estonia. In the case of the TII (Telecommunication Index), the first position in the ranking was recorded by Germany, and for the HCI (Human Capital Index) by Sweden. Poland was ranked 17th for OSI, 16th for HCI, and TII. Poland recorded much better results in the ranking in 2020 for OSI - 10, and HCI - 14, while worse for TII - 19. This indicates the dynamism of activities in the development of ICT technologies in the implementation of public services during the COVID-19 pandemic. The last place in the ranking for OSI was taken by Lithuania in 2020, and 2022 by the Czech Republic, while for HCI in 2020 and 2022, the 27th place in the ranking was recorded by Rumian, and for TII by Hungary.
Research in the EU shows that Poland is characterised by an average level of development and quality of public services provided through electronic distribution channels. Based on the data in Table 2, it can also be indicated that in the case of Poland, the EGDI indicator decreased from 0.8531 in 2020 to 0.8437 in 2022.

3.2 Multi-criteria assessment of ICT technologies in Poland – comparative analysis using TOPSIS, VIKOR and Hellwig methods

The development of e-government services at the state and local government levels was assessed based on the Statistics Poland reports on the information society in Poland published in 2017-2022. Table 4 presents data on government entities' access to a broadband Internet connection. Their analysis allows for the conclusion that all government entities, district offices, and marshal offices had permanent Internet access in 2020-2021. For municipal offices, the percentage of access accounted for between 99.7-99.9% in 2019-2021. Therefore, it can be concluded that the entities surveyed had no problems with broadband access.

Table 4. Access to the Internet in public administration units (in %)

Specification	State administration	Self-government administration			
		Total	municipal offices	District offices	marshal offices
2019	99.1	99.8	99.7	100	100
2020	100	99.9	99.8	100	100
2021	100	99.9	99.9	100	100
2022	100	99.8	99.8	100	100

Source: own elaboration based on www.stat.gov.pl (15-04-2023).

The data on equipping employees of public administration entities with mobile devices with Internet access are slightly different (Table 5). Although the COVID-19 pandemic periodically forced remote work and officials had to be equipped with appropriate devices to guarantee Internet access, it can be concluded that this area

still needs to be addressed. Government officials are the best equipped, with as much as 51.4% in 2021 vs. 30.4% in 2016, followed by marshal offices (42.4% in 2021 vs. 15.9% in 2017). On the contrary, employees in municipal offices (18.5% in 2021 vs 11.7% in 2017) and district offices (18.7% in 2021 vs 13.7% in 2017) were equipped with portable devices with Internet access to the smallest extent. However, it should be emphasised that during the period studied, a progression of the analysis indicator of all types of the entities surveyed was noticeable (Table 5). This confirms the intensification of the activities of public administration entities in the digitisation of public services and the development of e-government. In 2022, 49.1% of government administration employees were equipped with portable devices with Internet access, and 214% of local government administration employees, while the number of employees of municipal offices decreased from 18.5% in 2021 to 17.8% in 2022.

Table 5. Employees of public administration units equipped in mobile devices with Internet access by type of units (in %)

Specification	State administration	Self-government administration			
		Total	municipal offices	District offices	marshal offices
2017	30.4	13.0	11.7	13.7	15.9
2018	32.9	15.0	13.5	16.3	19.8
2019	36.7	15.5	14.2	15.9	22.2
2020	47.3	19.2	17.5	18.2	36.1
2021	51.4	20.2	18.5	18.7	42.4
2022	49.1	21.4	17.8	20.9	49.6

Source: own elaboration based on www.stat.gov.pl (15-04-2024).

Public administration entities were most likely to provide employees with remote access to the office's email (95.5% in 2021 vs 71% in 2017). Furthermore, in 2021 and 2022, 72.7% of offices guaranteed access to and the option to modify business documents (only 13% in 2017), and 70.0% (14.1% in 2017) and 68.8% (in 2017, 17.8%) of offices, respectively, guaranteed access to data and applications dedicated to the entity, as shown in the data contained in Table 6.

Table 6. The objectives of using remote Internet access in public administration units

Specification	in % of total units			
	Access to business e-mail	Access and possibility of modifying business documents	Access to data	Possibility of using dedicated business applications
2017	71.0	13.0	14.1	17.8
2018	82.9	22.2	24.5	29.0
2019	86.8	28.3	28.7	34.0
2020	95.0	65.9	63.4	62.8
2021	96.0	72.7	70.0	69.0
2022	95.5	72.7	70.0	68.8

Source: own elaboration based on www.stat.gov.pl (15-04-2024).

For the government entities analysed in the present study, one of the primaries means of sharing resources with employees and a tool for communication within the entity was the Intranet (internal network), with 63.7% (2.3% more than in the previous year) used in the entities in 2022, including 96.4% of government entities (84.6% in 2017) and 62.5% of local government entities (33.2% in 2017).

Table 7. Public administration units having an Intranet by type of unit (in %)

Specification	State administration	Self-government administration			
		Total	municipal offices	district offices	marshal offices
2017	84.6	36.2	33.2	52.4	87.5
2018	86.6	40.1	36.9	58.3	93.8
2019	92.0	52.1	49.6	66.7	93.8
2020	92.9	56.4	54.1	69.5	93.8
2021	94.5	60.1	57.9	72.6	93.8
2022	96.4	62.5	60.4	74.2	93.8

Source: own elaboration based on www.stat.gov.pl (15-04-2024).

The internal network was used to the greatest extent (87.8% in 2021) to exchange data between the entity's departments, and to a lesser extent (39.3%), to serve as a group work system, or (39.2%) to use a newsletter. The Intranet was used in the customer service system by 15.4% in 2021.
In 2022, the intranet was most often used in government administration to enable the use of an information bulletin (93.4%), while in local government administration - as a data exchange system between departments of the unit (86.8%).

Table 8. IT services and ICT training in public administration units (in %)

Specification	IT services		ICT training in public administration units	
	Appointed employees or organisational unit	External entity	training for ICT specialists	training for other persons employed
2017	62.1	12.3	68.1	68.6
2018	32.6	11.8	64.4	82.5
2019	52.4	13.5	66.0	81.3
2020	55.9	14.0	66.7	81.9
2021	56.6	14.6	70.6	80.6
2022	57.4	15.2	72.3	83.2

Source: own elaboration based on www.stat.gov.pl (15-04-2024).

The development of ICTs means that the efficient operation of public administration requires constant upgrading of employees' competencies, which increases the interest in training for both ICT specialists and other employees. Data in this regard are presented in Table 8. It can be concluded from these data that the number of training courses for both employees with competencies in IT services from outside public administration entities and other employees in Poland increased between 2017 and 2021. The highest percentage, of more than 80% (approximately 69% in 2017), was training for other public administration employees.

In 2022, the percentage of public administration entities that used a broadband connection was 99.9%. The percentage of employees equipped by offices with mobile devices with Internet access also increased by 1.9% compared to the previous year, accounting for 29.7%. To a similar extent, the percentage of entities using electronic document management has increased, reaching 83.1% in 2021. It should also be noted that a third of the entities surveyed identified electronic document management as the primary means of documenting the progress and handling and resolution of administrative matters. In the process of implementing electronic services, up to 99.8% of public administration entities used the electronic inbox available on the ePUAP platform, and more than 21.4% of entities had their electronic inbox projects implemented. About 36% of the entities declared monitoring the number of cases handled electronically, with government entities doing so much more often (66.4%) than those in local governments (34.4%). The index analysis confirmed the development of e-government services in Poland, although it is less evident in the case of local government administration. The actions of the public administration in Poland should therefore be targeted in the area of local entities.

The data indicated above illustrate the intensification of activities in the field of e-government development in Poland. To examine a synthetic measure of the development of e-government at individual levels of public administration, an attempt was made to conduct a multi-criteria analysis, three methods: TOPSIS, Hellwig, and VIKOR were compared. The study was based on 19 indicators (Fig. 1), the results of which are summarised in Table 9. Depending on the approach chosen, the obtained rankings are characterised by slight differences. Regardless of the method adopted, as can be seen from the information content of Table 9, over the analysed period, the discussed types of unit occupied relatively stable positions.

Analysing the information content of Table 9, it can be indicated that in the TOPSIS method, the highest level of the synthetic indicator is characteristic of marshal offices, for which the values are in the range (0.7302 - 0.6763), thus being considered an ideal solution (pattern) over the analysed period. Period. Second place in the constructed ranking is taken by government administration (0.4276-0.4753). The next 3rd place is occupied by total self-government offices (2020) and district offices (2021-2022). In the penultimate place in 2020 are district offices (0.3632) and municipalities offices (0.3890-0.3983). The anti-pattern (anti-ideal solution) are municipal offices (0.3618) in 2020 and total in 2021-2022 (0.3850-0.3903).

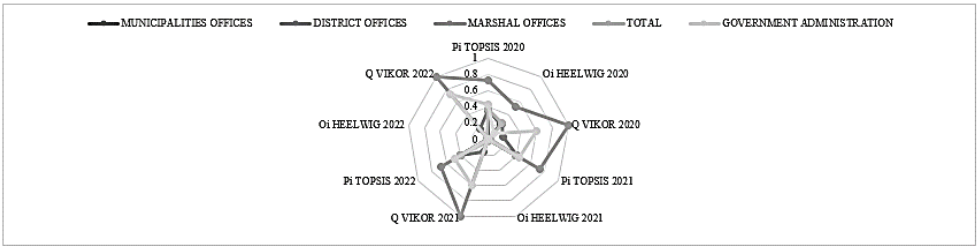
In the Helliwg method, as in the case of TOPSIS, marshal offices are considered the ideal solution, for which the synthetic indicator oscillates in the range (0.5184-0.3924). Total offices (0.2538) and district offices (0.3077-0.2758) also have values very close to the ideal solution. The next place in the ranking goes to district offices (0.2507) in 2020 and total self-government administration (0.2434- 0.2203) in the next two years. In fourth place (as in the case of the TOPSIS method, except for 2020, when the units discussed can be characterised as an anti-pattern) are the values of the synthetic measure for municipality offices. The lowest similarity to the ideal solution, for which the synthetic indicator ranges from 0.1005 in 2020 to 0.0442 in 2022, is shown by the government administration.

Table 9. Ranking of TOPSIS, Hellwig and VIKOR methods of ICT use in public administration units

Specification		2020					2021					2022				
		Pi TOPSIS	Qi HELLWIG	Q VIKOR	TOPSIS Rank	HELLWIG Rank	VIKOR Rank	Pi TOPSIS	Qi HELLWIG	Q VIKOR	TOPSIS Rank	HELLWIG Rank	VIKOR Rank	Pi TOPSIS	Qi HELLWIG	Q VIKOR	TOPSIS Rank	HELLWIG Rank	VIKOR Rank
MUNICIPAL OFFICES		0.3618	0.2351	0.0000	5	4	5	0.3890	0.2204	0.0000	4	4	5	0.3983	0.1988	0.0000	4	4	5
DISTRICT OFFICES		0.3632	0.2507	0.1802	4	3	3	0.4004	0.3077	0.1613	3	2	3	0.4018	0.2758	0.1639	3	2	3
MARSHAL OFFICES		0.7302	0.5184	1.0000	1	1	1	0.7262	0.4592	1.0000	1	1	1	0.6763	0.3924	1.0000	1	1	1
TOTAL SELF-GOVERNMENT ADMINISTRATION		0.3690	0.2538	0.0210	3	2	4	0.3850	0.2434	0.0293	5	3	4	0.3903	0.2203	0.0313	5	3	4
GOVERNMENT ADMINISTRATION		0.4276	0.1005	0.6006	2	5	2	0.4407	0.0610	0.6027	2	5	2	0.4753	0.0442	0.7304	2	5	2

Source: own elabortaion.

Figure 4. Ranking of e-government development at individual levels of public administration in Poland



Source: own elaboration.

Also, in the VIKOR method, as in the case of the two previous methods, the highest level (standard) of the synthetic indicator throughout the entire discussed period is typical for marshal offices, for which the values are at the level of 1.0000. Similarly, for the TOPSIS method, the second place in the ranking constructed using the VIKOR method is taken by the government administration (0.6006-0.7304). In the years 2020-2022, the remaining units discussed also occupy permanent positions in the ranking. In the ranking constructed using the VIKOR method, the alternative third place is taken by the district offices. The next place in the ranking is typical for total self-governance offices, for which the synthetic measure is 0.0210 in 2020, 0.0293 in 2021, and 0.0313 in the last analysed year. In turn, the furthest from the ideal solution (anti-pattern) were municipalities offices, for which the synthetic indicator has a value of 0.0000. The values of the synthetic indicators obtained based on both the TOPSIS, Hellwig, and VIKOR methods are similar. In the period under consideration, the analysed units occupy permanent positions in the constructed ranking only in the case of the VIKOR method.

In the case of the TOPSIS and Hellwig methods, the ranking positions are relatively constant. Changes, if any, do not exceed more than two items. The constructed synthetic measures using the TOPSIS (Pi), Hellwig (Qi), and VIKOR (Q) methods indicate that in 2020-2022, marshal offices implemented ICT in Polish public administration units to the greatest extent, playing the role of a leader (positive-ideal solution) in 2020-2022. The worst practices (negative-ideal solution) in the use of information and communication technologies characterised municipal offices in the case of the VIKOR method throughout the entire period. However, in the case of the TOPSIS method, they occurred both in the case of municipal offices in 2020 and public administration units in general in 2021-2022. In turn, in the case of Hellwig's method, the government administration shows the least similarity to the ideal solution, taking the last 5th place in the ranking over the analysed period.

3.3 Discussion

Multicriteria methods are used in many different areas of research. Used to indicate the best solution. The research conducted so far has been conducted in the areas of

management (e.g., design or production) and economics, marketing, environmental sciences, tourism, education, engineering, energy and fuels, logistics, supply chain, health care, risk or green sustainable science and many others (Yazdani and Graeml 2014; Basílio et al., 2022).

Initially, Hellwig's method was used to assess individual countries analysed in terms of their level of development, resources, and staff competence structure (Roszkowska et al., 2024). Based on specific criteria, the information capacity method was also used to discuss the quality of websites. (Ziemba and Budziński, 2012). In the context of ICT, Hellwig's method has also been used in the analysis of digital competencies considered through the prism of the young generation in Poland and other European countries. Witczak-Roszkowska (2022) points out that in terms of digital competencies, young Polish citizens in the age group (16-24) occupy a distant place, taking into account, among others, such aspects as online activity, ability to use databases, development of digital content or use of ICT. The Finns are the best at this. In the mentioned study, the author notes that a particularly low level of digital competencies among young people is visible in Bulgaria and Romania.

Previous ICT research based on the TOPSIS method focused on the use of information and communication technologies in 2019 in enterprises located in Europe. The research conducted shows that Finland demonstrates the best practices in this area. Romania was identified as the anti-pattern. Poland ranks 27th in this ranking. Enterprises operating in these countries, to improve the competitiveness of the economic well-being of the entire country, as the authors point out, should strive for more intensive use of ICT, for example through e-commerce or e-business (Vasilić et al., 2020).

The ranking based on the TOPSIS method was also developed by Di Caprio & Santos-Arteaga (2023) to decide on entering the market due to the level of ICT advancement in a selected group of European countries. The TOPSIS method - combined with the AHP method, was also used to analyse the quality of courses offered by the University of Economics Ho Chi Minh City (UEH) based on Newhouse ICT indicators (Truong and Nguyen, 2023). The AHP method was also extended to include VIKOR, on this basis identifying the determinants of success affecting e-logistics activities Özekenci, (2023). Using, among others, methods of VIKOR Su et al. (2022), analysed the state of the digital economy in selected Chinese provinces. In the context of ICT, the VIKOR method has also been used to identify and quantify the difficulties associated with using the Internet of Things (IoT) in implementing sustainable supply chain management (Yang, 2022). Using the mentioned multi-criteria method, the level of digital transformation was also discussed through the use of technological solutions implemented under the European Digital Decade strategy, thus analysing the digital sovereignty of large enterprises in the European Union (Sztorc and Savenkovs 2023).

In connection with the above, it can be noted that the use of linear ordering methods is used in the study of the ICT sector. However, there is a lack of research on assessing the development of e-government at the local level. The research conducted in this study fills this gap and also indicates the dynamic development of

ICT technology in public administration units in Poland, although, to a lesser extent, this is the case in municipal offices. The use of multi-criteria analysis measures in the research allowed us to determine the ranking of individual levels of public administration in Poland in the development of ICT technology. The constructed synthetic measures using the TOPSIS and Hellwig methods indicate that in the years 2020-2022, ICT technologies were implemented to the greatest extent in Polish public administration units by marshal offices (leader). In the case of the TOPSIS method, in 2020 the anti-pattern was characterised by municipalities offices, and in 2021-2022 public administration units in general. Based on synthetic measures constructed using multi-criteria methods, it should be stated that in most cases, more convergent results occur in the case of the TOPSIS and VIKOR methods, which may result from similar assumptions. Following Shekhovtsov and Salabun (2020), it should be noted that both of the mentioned methods are comparable and/or alternative to each other. However, Hellwig's method shows greater differences, especially in the case of government administration. Therefore, in this case, based on the analysed data, we believe that it is more appropriate to compare the TOPSIS and VIKOR methods, which we recommend for further research.

Surveys have indicated an increase in the use of e-services provided by state and local government offices, with a growing group of citizens more willing to use the Internet. This is due to the many benefits of implementing e-government, such as time savings, a wide range of options, convenience, overcoming geographic and time barriers, and financial savings. Developed and developing countries are moving away from the paradigm of the state or local government offices as bureaucratic and faceless organisations, and moving toward the implementation of innovative technologies, using ICTs, and treating citizens as customers (Dillon et al., 2015). This process began in the late 1990s when governments at all levels launched e-government projects aimed at providing electronic information and services to citizens and businesses (Chen & Gant, 2001). Over the years, the development of e-government allowed citizens, businesses, and government entities to conduct various event/customer-focused online transactions.

As argued by Jedlińska and Rogowska (2016) currently Poles still make limited use of e-government solutions due to their imperfection. Every effort should be made to make the presentation of the desired content more comprehensible and transparent, thus avoiding discouragement and digital and IT exclusion of the public. The use of modern technological solutions is not only a prerequisite for efficient administration but provides an opportunity to increase citizen participation in decision-making on public affairs. Information and communication technologies (ICTs) are playing an increasingly vital role in people's daily lives, revolutionising work and leisure and changing the rules of doing business (Solinthone and Rumyantseva, 2016).

An important element in the development of e-government is training for employees in public entities. The presented research on training courses organised in 2017-2022 for public administration employees in Poland shows their progression. Training is a key component of improving work performance using ICTs. This was confirmed by a study conducted by Claver-Cortés, de Juan-Espinosa & Valdes-Conca (2016)

on training activities aimed at Spanish public administration employees to assess managers' perceptions of ICT areas and the impact caused by the introduction of e-government strategies. These researchers showed that city councils have increased investment in the technical aspects of e-government, but not in developing the competence to use the technology. Public sector employees did not see significant improvements in the way they worked and their performance levels, which leads to the conclusion that underinvestment in competency training does not promote a sense of efficiency in the delivery of public services.

Although e-government has become a reality and ICT technologies are increasingly being used by public administration, there are still many barriers that discourage governments from developing new or existing e-government applications (Eynon, Dutton, 2007). Among the most frequently cited concerns are underdeveloped infrastructure, lack of comprehensive preparation of citizens to freely use e-government functionalities, or psychological barriers regarding the security of the Internet as a place to communicate with public sector entities (Dąbrowska et al., 2009, p. 138). Citizens are reluctant to use electronic services until they have confidence in the system. They can use the tools offered by e-government only when they are sure that their privacy and security are not put at risk and that there is a compelling reason to use them (Worrall, 2011). As a result of the COVID-19 pandemic, societies have been forced, in a way, to have to use e-government services, but will the post-pandemic period bring further rapid development of the ICT sector, especially e-government? This area should be a field for further exploration and scientific inquiry.

4. Conclusions

The main aim of the present research was to assess the level of development of public e-government in Poland over the past few years. A major influence on ICT implementation in state and local government entities was the COVID-19 pandemic. The outbreak of the pandemic was unexpected and led to many changes in various aspects of socioeconomic functioning. The real threat to health and life has caused a change in social behaviour. Citizens were forced to deal with many official matters through electronic distribution channels of public services. Compared to other EU countries, Poland is at an average level of implementation of e-government services, ranking 34th based on the EGDI index. The survey helped address the research questions. An in-depth analysis of data presented by Statistics Poland showed that between 2017 and 2022, the role and scope of e-government services increased as state and local government offices made their services available to citizens via the Internet. The indicator analysis confirmed the development of e-government services in Poland, although it is visible to a lesser extent in the case of local government administration. The activities of public administration in Poland should therefore be focused on local units. The use of multi-criteria analysis measures in the research (TOPSIS, VIKOR, and Hellwig) allowed us to determine the ranking of individual

levels of public administration in Poland in the field of ICT development. The leader in the ranking according to all three methods is marshal offices. The last position in the ranking according to the VIKOR method is taken by municipalities offices, and according to the TOPSIS and Hellwig methods they are in the penultimate position (4th). The use of multi-criteria analysis measures in the research allowed us to determine the ranking of individual levels of public administration in Poland in the development of ICT technology. In Poland, offices operating at the voivodeship level are characterised by the greater adaptation of e-government, while offices operating at the commune level still require further intensified work.

Conflict of Interest Statement

There is no conflict of interest.

Authors Contributions

The author/authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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