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This volume represents the proceedings of the Main Conference including the Posters track of the 16th International Conference on ICT in Education, Research, and Industrial Applications, held in Kharkiv, Ukraine, in October 2020. It comprises 41 contributed papers that were carefully peer-reviewed and selected from 103 submissions. The volume is organized in five parts. Parts I to IV contain the contributions to the Main ICTERI Conference tracks, structured in four topical sections: (I) Advances in ICT Research; (II) Information Systems: Technology and Applications; (III) Academia/Industry ICT Cooperation; and (IV) ICT in Education. Part V contains the contributions of the Posters track.

Preface

In these extraordinary and challenging times, it is our great pleasure to present you the proceedings of the Main Conference of ICTERI 2020, the sixteenth edition of the International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications, held in Kharkiv (Ukraine) on October 5-10, 2020. ICTERI focuses on ICT research advances, industry/academic applications of Information and Communication Technologies, design and deployment of ICT Infrastructures and the emphasis is also put on real-world applications of ICT solutions. The current edition has a special focus on (i) ICT research advances, (ii) information systems technologies and applications, (iii) academic and industry cooperation in respect to Information and Communication Technologies, and, more relevant than ever, (iv) the role of ICT in Education.

The ICTERI 2020 Main Conference proceeding is structured following the above mentioned four thematic tracks and also contains a chapter presenting the short papers which constituted the program of our Posters track.

The conference program was complemented by a PhD Symposium, a Posters track, and six co-located workshops. The proceedings of the PhD Symposium and co-located workshops are published as separate volumes.

The rationale behind the Ph.D. Symposium sub-event is to offer an expert environment for the presentation of the tractable ideas and early results of PhD projects or other research aiming at receiving a PhD. The Posters track at ICTERI 2020 called for solution presentations and novel technology applications at an early stage of development.

Overall, the ICTERI 2020 Main Conference, with its Poster Track, attracted 103 paper submissions. Out of these submissions, we accepted 26 high quality and most interesting papers for the Main Conference program, in particular 14 full papers, 6 short papers, 5 discussion papers, 1 extended abstract, and 15 short poster papers. Main Conference papers were presented in 9 sessions. The posters were presented in three poster sessions. The acceptance rate was 39.8 percent.

The conference would not have been possible without the support of many people. First of all, we would like to thank all the authors who submitted papers to ICTERI 2020 and thus demonstrated their interest in the research problems within our scope. We are also very grateful to the members of our Program Committee for providing timely and thorough reviews and, also, for being cooperative in doing additional review work. We would like to thank the local organizers of the conference, the steering committee and also the team of the former ICTERI conference, especially Vadim Ermolayev, for their help and advice. Their devotion and efficiency made this instance of ICTERI a very interesting and effective scientific forum.

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Regional Policy of Advanced ICT in the Minds of Forming Economy Knowledge

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Abstract. The purpose of this article is to determine the disproportions of the development of the regions of Ukraine and establishing common characteristics in the processes of spreading the latest information and communication technologies. This will determine the prospects for the formation of a knowledge economy in the country. The method of generalization and systematization, cluster analysis and cartography were used to determine the object of research. The clustering of the regions of Ukraine for the conditions of 2009 and 2018 years proceeded. Five homogeneous clusters were identified that differ in the degree of dissemination of information and telecommunication technologies. This was characterized by different levels of willingness for the formation of the knowledge economy in a separate region and the whole country. There were established vectors for the strategic development of the regions of Ukraine for each cluster that are directed at the spreading of information and telecommunication technologies. They serve as a key tool for the formation of the knowledge economy in the country. There were also substantiated the possible results from the implementation of measures to improve the functioning of the country in this field of activity.

Keywords: Region, Information and Communication Technologies, Knowledge Economy, Cluster Analysis, Internet, Mobile Communication.

1 Introduction

The use of information and telecommunication technologies (ICT) at the regional level accelerates the formation of a knowledge economy (KE) in the country. This is to create conditions for sustainable socio-economic growth and the country's gradual recovery from the financial and economic crisis. The functioning of e-governance, the increase in the Internet audience from the population, enterprises, institutions and the public sector, the increase in the volume, final usefulness and quality of Internet

services, the increase in the demand for mobile services, the development of information infrastructure and free access to its use will accelerate processes for obtaining, disseminating and accumulating knowledge and expanding the potential capabilities of users of the latest ICT. Therefore, the use of ICT at the regional level as a factor in enhancing the economic development of a region and a knowledge-based country is very relevant. At the same time, the main vector of research should be aimed at forming the foundations of a regional policy for the dissemination of ICT in the regions of the country, it will gradually bring it closer to KE [1].

2 Methodology and Tools of Research

Five statistical indicators were selected as the research methodological base, which from different sides characterize the level of ICT spread in the regions of Ukraine as one of the main tools for its knowledge-based development, specifically: the number of subscribers by type of communication services (Internet services, mobile communications, cable television), the income of enterprises from their provision (Internet services and mobile communications) [2]. The information base of the study was the statistical data on the use of ICT, presented in a regional context and reflected by the State Statistics Service of Ukraine in the statistical bulletin "State and development of communication in Ukraine" [3; 4]. At the same time, the choice of indicators was limited by the incomplete reflection of the statistical information given by regions and was based on those data that were provided for public use. According to the chronological basis of the study, there were taken two years – 2009 and 2018 [3-6]. The choice of the starting point of the study is due to the fact that it was the year that official statistics began to take into account the studied indicators for the regions of Ukraine. The final point for the study was the last year of reporting the State Statistics Service, which was used to group regions by selected indicators. So, the methodological basis of the study was formed in such a way that should allow an objective assessment of the dynamism of ICT distribution processes in the regions of Ukraine and establish trends in the known development of its regions.

There can be used two groups of methods, in order to identify development patterns of the regions of Ukraine according to the criterion of the spread of ICTs and the prospects for the formation of KE and the installation of its similar essential features [7]. The first group includes the methods of the main components and factor analysis, which allow us to represent the original attribute space in the form of a certain combination of signs. However, the main drawback of these methods is certain difficulties that arise at the stage of interpretation of the research results. The methods of cluster analysis, the extreme grouping of signs and other methods related to the second group allow us to avoid these difficulties and therefore are more appropriate for use. Consequently, in order to assess the degree of ICT spread in the regions of Ukraine, there was chosen the cluster analysis method, which allows forming homogeneous groups (clusters) based on the analysis of the initial features.

The application of the cluster analysis method is based on a preliminary determination of the number of clusters on which the regions of Ukraine will be grouped. To do this, using the Sturges rule, the optimal number of clusters with equal intervals was calculated. It was found that the optimal number of clusters for solving

the problem of compressing the information space of regional data by the criterion of the degree of ICT distribution is five.

In the process of performing cluster analysis, there is the proceeding of initial digital or textual information, which should be normalized and presented as functions of the distance between the indicators. A measure of the relationship between quantitative features (in our case, they are indicators of assessing the spread of ICT in the regions of Ukraine) are Euclidean distance indicators. Technologically, this process was carried out using the "Data Analysis" toolkit of the Science Hunter portal [8].

3   The Results of the Clustering of the Regions of Ukraine by the Degree of Spreading ICT

Table 1 shows the distribution of the regions of Ukraine among clusters, where the bold type indicates the regions that have a stable membership in the cluster for two years of research [2].

Table 1. The Results of the Clustering the Regions of Ukraine In Terms of the Distribution of Information and Communication Services in 2009 and 2018.

Cluster	2009	2018
I	**Vinnytsia**, **Zhytomyr**, **Kyiv**, Cherkasy, **Chernihiv** regions	**Vinnytsia**, **Zhytomyr**, **Kyiv**, Zaporizhia, Lugansk, Lviv, Mykolayiv, Poltava, Sumy, **Chernihiv** regions
II	**Volyn**, **Zakarpattia** **Ivano-Frankivsk**, **Kirovograd**, Mykolaiv, **Rivne**, Sumy, **Ternopil**, **Kherson**, **Khmelnitsky** regions	**Volyn**, **Zakarpattia** **Ivano-Frankivsk**, **Kirovograd**, **Rivne**, **Ternopil**, **Kherson**, **Khmelnitsky**, Cherkasy, Chernivtsi regions
III	**Dnipropetrovsk**, Donetsk, Kharkiv regions	**Dnipropetrovsk** region
IV	Zaporizhzhia, Luhansk, Lviv, Poltava regions	Donetsk, Kharkiv regions
V	**Odesa** region	**Odesa** region

Based on the typification of the structural features of the regions of the country, five clusters were discovered with an unequal level of ICT use, characterizing various basic conditions for the formation of KE in them. The results of scaling and a generalized assessment of the state of development of ICT services in established clusters of Ukraine are given in Table 2.

Table 2. Generalized values of indicators for assessing the spread of information and communication services in cluster entities of the regions of Ukraine in 2018.

Indicators		Clusters				
		I	II	III	IV	V
Number of subscribers	Internet services				▒	▓
	Mobile Connection	▒		▓	▓	▒
	Cable TV			▓		▓
The income of enterprises from the provision of	Internet services					▓
	Mobile Connection	▒		▓	▓	▒

Legend:

☐ – unsatisfactory and minimum possible indicator level

▒ – satisfactory and average level of indicator

▓ – the highest possible level of indicator

The general trend for cluster I is an increase in the number of Internet service subscribers, a decrease in the number of cable television subscribers, and slight fluctuations in the direction of increasing the number of mobile subscribers. So, the interest of enterprises and the population is shifting towards Internet services, which opens up enormous opportunities for the development of KE in regions of Ukraine.

The regions of cluster II demonstrate the poor state of ICT distribution in Ukraine. This means, that their condition regarding the use of telecommunication tools and communication means remains unsatisfactory and hinders the dissemination of the knowledge component of the socio-economic development of the country. The volume of services provided on the Internet for the region is distribution and using information by regional enterprises are limited [5; 6].

Cluster III in 2009 included Dnepropetrovsk, Donetsk and Kharkiv regions, and in 2019 the cluster represents exclusively the Dnipropetrovsk region. In 2009, this cluster was characterized by maximum and above-average levels of all analyzed indicators of ICT distribution, with the exception of the number of Internet users.

Cluster IV in the base year consisted of Zaporizhzhia, Luhansk, Lviv and Poltava regions, which were characterized by the values of all the studied indicators below the average level and only the Lviv region had a value of the enterprise income from providing Internet services that exceeded the average level.

In 2018, the composition of the IV cluster completely changed which demonstrate the highest possible level of providing the population with mobile communications and high income from the provision of these services in comparing to other regions. This is due to increased consumer demand for mobile services due to the additional use of modern mobile gadgets, due to the interest of legal entities and individuals in acquiring information and telecommunication services, and an increase in the volume of mobile Internet traffic and coverage of the territory of the regions covered by 3G networks [9].

The atypical clusterization object that did not join any of the four clusters is the Odesa region, which became part of the V cluster. The cluster is distinguished by the maximum values of indicators of the number of consumers of Internet services and the income from their provision. However, the number of mobile subscribers in the region was less than the average level in Ukraine.

It should be noted that during the study period in the regions that were part of the II, IV, and partially I clusters, there was a tendency to decrease the number of cable television subscribers, this can obviously be due to the appearance of new high-tech capabilities of television services.

It should be mention that the data that characterize the Donetsk and Luhansk regions were significantly affected by the processes of loss of Ukraine's control over part of its territory in the result of the military conflict. In this regard, it can be argued about the reliability and incompleteness of information in 2018.

4   Vectors of Regional ICT Dissemination Policy as a Tool for the Formation of KE

Based on the results of the study, it is proposed to develop the basic vectors of the regional ICT distribution policy (Table 3) in the regions of the country.

Table 3. Vectors of strategic development of the regions of Ukraine, aimed at the dissemination of ICT services as a tool for the establishment of KE in the region and the country.

Cluster	Strategic vectors of development
I	Active distribution of Internet services, support and further development of the mobile communications market, development of IT business
II	The development of markets for Internet services and mobile communications, developing the IT business by attracting and retaining IT specialists in the regions of the cluster, disseminating information about the possibility of information services from the outside local authorities and management, optimizing pricing for the provision of cable television services, increasing the density of coverage of communication networks and the Internet
III, IV	Accelerated development of the distribution of Internet-services, the development of IT business, the increase in investment in ICT, improving the quality of access to the Internet, the activation of grant writing in the field of ICT
V	Keeping the current state of ICT, diversification of ICT services, development of IT business, development of measures to improve the quality of information and communication services, loyalty programs for mobile subscribers and the Internet

Expected results from the implementation of measures to improve the functioning of the ICT sector:

- ❖ Improving literacy and the development of digital intelligence in the field of ICT for the population and personnel of enterprises. The motivation for new knowledge and application of the latest technologies.
- ❖ Development of information infrastructure in the regions, acceleration of the creation of SMART-city technologies.
- ❖ The growth of Gross Regional Product in Ukraine due to the development of the digital and network economy, creation of virtual enterprises/
- ❖ The development of micro entrepreneurship, small and medium-sized businesses due to its promotion on the Internet.
- ❖ Creation of new jobs based on the latest ICT.
- ❖ Stimulation of innovative processes in all spheres of life of the population and business.
- ❖ Ensuring the development of the process of formation of the KE in the regions of Ukraine.
- ❖ The emergence of wide opportunities for dialogue between the population, business, local authorities and the government.
- ❖ The development of informatization by accelerating the process of acquiring knowledge and transferring it among interested parties.

5 Conclusions

The study, based on cluster analysis, revealed the presence of five homogeneous cluster groups of regions of Ukraine, which differ in the degree of ICT distribution and a different level of readiness for the formation of KE in the country. The similarity regions of I cluster is due to an unsatisfactory quantitative measurement of the Internet audience and the low penetration of Internet services in all areas of the region's vital functions that are part of it. There is a satisfactory level of demand for mobile services and income from their provision.

Cluster II described the process of disseminating information and communication

services as unsatisfactory and minimal in terms of demand for Internet services, mobile communications and cable television and the income from their provision. That cluster requires more significant efforts when implementing regional strategies aimed at stimulating knowledge-based development in the regions, equalizing and further smoothing the imbalances between them.

The areas that are included in the III, IV and V clusters are characterized by advantages in the dissemination of ICT in comparison with other regions of Ukraine. So, cluster III as a part of the Dnipropetrovsk region has the maximum number of cable TV users. Cluster IV is the leader in the number of mobile communications subscribers. Cluster V has the largest audience of Internet users' service. Moreover, the V cluster demonstrates the best state in the processes of dissemination of information and communication services, indicates its uniqueness with respect to the selected research criteria, stability in the development of the use of the latest technologies, progressiveness and acceleration of ICT distribution. That is, the acceleration of the pace of the formation of KE in the Odesa region can be achieved through the tools of the network and digital economies, which can be realized by further supporting the spread of innovative technologies in all spheres of life.

So, the clustering the regions of Ukraine by the criterion of the spreading of ICT in them allowed us to establish significant disproportionate fluctuations in the state of the application in the areas of the latest communication technologies and determine priorities in the development of regional of regional policy. The development and implementation of functional strategies for regions will contribute to the accumulation of intellectual capital, open up greater opportunities for the development of business, science, education, accelerate the processes of their integration, and therefore the establishment of KE.

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