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Spatial Distribution of Information Society Development in Poland

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Abstract. This article overviews factors important to the development of information society (IS) in Poland, considers indicators of the current state of affairs and developmental dynamics of the IS development process, and proposes a certain research methodology. Our study assumes that network access (in a broadly construed sense) is a crucial factor in IS development and poses the following hypothesis: the index of population potential (modified to account for rank-order differences and demographic characteristics of geographical units) constitutes an appropriate measure of network accessibility, and thus in turn may serve as an index of IS development. This hypothesis is then verified on the basis of data for Poland's *voivodships* (regions). A Synthetic Index of Information Society (SIIS) is posited, constructed of partial indicators. This synthetic index and the individual partial indicators are correlated against the classical and modified population potential indexes. Based on a review of international and Polish literature, partial indicators are selected for which statistical data can be collected, to use in compiling the synthetic IS measure. Special attention is paid to spatial distribution in the degree of IS development.

Keywords: model of population potential, information society

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1. Information society – multifaceted definitions

Information society (IS) is descriptively defined in terms of two characteristics: the scope of universal access to information among the population (a condition colloquially known as a *well-informed society*) and the extent to which data transmission infrastructure is developed and widespread (known as *information and communications technologies*, or ICT), thus enabling information to be accessed and harnessed.

Information society is one of the most frequently used terms in describing and evaluating the advance of modern world civilization. We can risk asserting that the concept is oxymoronic in nature, like the concept of *artificial intelligence*; both notions meld the processing power of computers with the human intellect. This blurring of the boundary between man and machine was already pointed out by Bolter (1984). However, the universal trait of mankind – intelligence – should be stressed. And so, the arbitrariness observed in the use of the IS concept can be seen to stem from its metaphorical character, as well as from its applicability to various fields of science, ranging all the way from psychology, sociology, geography, economics, and business to computer science and data transmission.

IS-related notions have grown very popular over the past decade, even becoming in vogue, as is shown by numerous international (EU) and domestic projects. The overuse of the information and communications technologies (ICT) concept has led to a devaluation of both the topic as such and the terminology used.

IS research may be of a general or specialized (sectoral) nature. Physicists and technical scientists study the social impacts of the onset of information-based civilization (Zacher, 1998), i.e. the functioning of computer society, cyber-society. Economists, in turn, deal with the information sector as a distinct part of the economy, considering how to measure and describe its functioning (Dziuba, 2000). Another specialized approach looks at the legal issues in the emerging information society, above all involving computer crime, the privacy of personal data, and the protection of intellectual property (Szewc and Jyż, 1996). Sociologists, too, take an interest in IS-related issues, such as Zacher (1998), Krzysztofek (1998).

Yet despite the fact that IS research has become quite advanced in recent years, there is no universally accepted definition of IS or any consensus as to the meaning and scope of the term. Many researchers have debated the definition of IS itself, while others have even deliberated whether information society actually exists or is merely an idea. Marciszewski (1999) argues that there is no sharp division between one society which is an information society and others which are not, but instead we may speak of a scalar gradation, with one society being more of an information society than others. When writing was invented and disseminated back in Phoenician society, it became more of an information society that its neighbours. The same thing can be said about the impact of the invention of Arabic numerals, printing, binary notation, or Morse code, etc. Certain authors have claimed that information society is merely a buzzword being promoted by the European Commission, without any semantic content.

Despite the plethora of definitions, the information society concept can be brought down to a simple assertion: the information society era begins when a greater portion of a country's national product starts to be generated by the processing of information, rather than from industrial production. This idea is still a subject of brisk scholarly discussion in Poland and in Europe. It entails that the existence of information society is neither a matter of any decision decreed by authority nor a matter of conscious choice, but simply a consequence of a significantly high degree of economic development. A given country attains the level of information-based civilization if its existence and development are chiefly underpinned by economic entities that operate in the intellectual domain (Gamdzyk, 1999).

This type of approach, presented by de Solla Price to define the size of a population forming a specific social group, remains useful. Jonscher (1999) lists „information" occupations which employed 70.2 million people in the United States in 1990, accounting for 58% of the workforce. These professions were as follows: writers, artists, entertainers (2.1 m); teachers, lecturers, trainers (6.1 m); scientists, doctors, specialized professionals (8.9 m); managers, administrators (13.5 m); sales occupations (14.4 m); accountants, financial staff (6.0 m); technical support staff (5.1 m), and clerical and secretarial jobs (14.1 m). Attaining this level took the United States around 90 years – statistics indicate that the group of information occupations employed 5.1 million individuals in 1900, which then represented 18% of the workforce. The data from 1990 therefore meet the criterion posited in one of the definitions: more than half of society works in the information sector, with the caveat that this particular set of professional groups is not exclusively American and seems to be highly debatable. These data are confirmed by Mattelart and Mattelart (1998), citing a report by Porat from 1977. According to Porat, in 1966 information-related activities represented 47% of the US workforce and about the same percentage of the gross national product. Porat divided the information sector into three categories: financial, insurance, and accounting information; cultural information; and knowledge/ know-how (patents, management, consulting, etc.) We can assume that the above-listed professional groups form the foundation of information society.

The term „information society" is already well rooted on both sides of the Atlantic and in Japan, although it is understood in various ways. In the colloquial understanding IS means a society which utilizes various types of modern technologies for gathering, analysing and transmitting information, in other words the instruments necessary for utilizing these knowledge-creating technologies. The widespread use of these technologies is accompanied by organizational, economic, and social change which has an impact on all domains of human life and activity.

The problem of constructing a proper definition is difficult, because the information society concept is broad while at the same time vague and fluid. Many definitions of IS can be found in the literature. Reviews of definitions can be found in such works as Goliński (1997) and Dziuba (2000). Information's role in modern society is predominately described using terms such as *significant*, *important*, and *dominant*. The definitions share a common underscoring of the importance of information and ICT for practically all aspects of modern life.

Stages are identified in the development of IS (which we take from Sysło (2000), following a UNESCO report from 1994): automation – the development of the basic infrastructure, information – the spread of information and media to a significant segment of society (users), and communication – a state in which most or all computers are connected to the network and communication processes affect all of society.

Existing theoretical analyses enable us to relate the understanding of the term *information society* to four meanings: an ideological sense, where IS is defined in terms of state policy towards ongoing economic and social transformations; an evolutionary sense, relating to well-known concepts of developmental waves (agriculture, industry, knowledge and communication) and the specific types of societies ascribed to them (agricultural, industrial, information societies); a technological sense, where economic and social development is identified with the spectacular advancement of information technology, transforming systems of labour, employment, governance, education, and administration, giving rise to new models of culture and civilization; and a cognitive sense, involving the positing of sociological theories to identify the analytical principles underlying the shaping of information society.

These theories are dominated by two groups of views: the first group takes the approach of treating information society as a developed, separate social structure, a consequence of the evolution of post-industrial society. The second group of views, in turn, holds that the ongoing changes do not affect society as a whole, but only certain portions thereof. On this approach, information technologies are treated as one often many factors contributing to partial changes of social structure, without any special impact on its qualitative transformation (Matusiak, 2005). Another approach is the layered model proposed by Kubicek (1999) to systematize and structure the issues, a model built around information and communications technologies.

2. Data transmission infrastructure

The field of telecommunications is among the most important and most dynamically development elements of the material basis of the entire economy. Its functioning and development as an element of technical economic infrastructure is one of the crucial factors for any social and economic transformation, and therefore the development of the telecommunications network should precede the development of all other production and service facilities. We can even assert that access to telecommunications services can serve as a tool in studying the degree of socioeconomic development.

Telecommunications services constitute an important element of the infrastructure of access to spatial data and related services. Spatial data quality and service reliability translate directly into the high quality of services involving access to spatial data.

Given the current state of telecommunications infrastructure in Poland, we can presume that every Polish resident or institution with Internet access enjoys basic access to spatial data. Nevertheless, taking advantage of the full range of spatial data on offer from providers and the functionality of related additional services requires broadband access. It therefore becomes necessary to expand fiber-optic backbone based Internet infrastructure over as much as the country as possible.

Many places in Poland already have local, public Wide Area Networks (WANs), most often developed by academic centres, sometimes in cooperation with local governments. Networks are used by spatial information systems both to serve the internal needs of public offices and institutions, and to provide access to spatial data (such as via information kiosks, computer stations set up in libraries).

Aside from fixed-line infrastructure (cables and fiber optics), wireless telecommunications infrastructure plays a huge role in the development of IS. Mobile services are based on access to 3G mobile telephony networks and/or to GPS signals. Decreasing prices of subscriptions, data transmission services (e.g. via GPRS) and mobile phones and palmtops are encouraging the use of spatial data in a great many fields of life.

The degree of development of data transmission infrastructure is one of the basic categories enabling a given society to be measured in terms of its informatization (Porębski, 2003). However, analysing the development of infrastructure is hampered by the ongoing integration of technical hardware belonging to three sectors: data transmission, the information sector, and the electronic media. Highly advanced countries evidence a high degree of convergence between the sectors, and thus a higher level of development of information infrastructure.

On the one hand there is a supply of telecommunications services, while on the other there is demand, i.e. users, and it is on users knowledge and qualifications that their harnessing of the available telecommunications (data transmission) tools and wide range of telecommunications services on offer depends.

There are both stimulators and impediments in the development of telecommunications. Factors stimulating such development include the following:

– decreasing costs of telecommunications services,
– easier access to information (business information, personal information) and multimedia resources (books, photos, films, music, games),
– new services – email, online banking, multimedia services in communications networks (e.g. videoconferencing), e-commerce,
– remote education,
– computerization and e-business.

Factors which impede the development of telecommunications include:

– insufficiently developed communications infrastructure (the absence of broadband networks),
– absent or insufficient legal regulations for telecommunications, operator ownership issues, service market liberalization,
– liberation of subscriber loops,
– a lack of regulations for citizen-citizen communications, citizen-state communications (filing tax returns, electronic signatures, online journal of laws), and international communications,
– the technological level of the economy and links to the world economy,
– the prevalence of network use as a medium of information access,
– the affluence of society,
– education and an awareness of needs.

Studies of data transmission network accessibility also take account of other phenomena occurring in information society. These include: the appearance of innovations (new technologies and functionally diverse devices), social adaptation to or rejection of new technologies, the spatial diffusion of innovations, processes involving the technological and media convergence of functionally distinct networks as a consequence of the introduction of digital data transmission networks (cable and radio).

To date, no analysis of data transmission service accessibility throughout Poland has been carried out, and thus no synthetic index measuring access to the network or to data transmission services has so far been developed. This state of affairs is probably due to difficult and costly access to the data that is only now being gathered by the Central Statistical Office of Poland (GUS) in its IS-related research. Telecommunications services are currently fully in the hands of the private sector.

Within the Polish literature, IS has been studied by Hoff (1991, 1995), Goliński (1997) and Dziuba (2000). These studies were small in scale and essentially amounted to comparisons of the situation in specific countries. These authors concluded that the tools so far developed for measuring information society are only partly satisfactory, either because they are very complex and based on hard-to-obtain statistical material, or because they are significantly simplified and insufficiently explanatory.

2.1. Overview of IS methods and studies

The complexity of the processes whereby innovations arise, are adopted, and become diffused stems from the interaction of the complex socioeconomic structures, including technologies and social structures, engaged in the common process of generating and adopting innovations (Frenken, 2005). This necessitates the use of methods based on complexity theory in analysing data transmission network access. Models used in this type of research include the following:

- fitness landscape models,
- network models,
- percolation models (simulation of complex systems characterized by different behaviour after a certain threshold is crossed),
- models of spatial interactions (gravitation and potential).

The term *complexity* may refer to interactions between components of technological systems or interactions between network structures and network agents.

Most models are based on certain indicators measuring the spatial diversification of the phenomena studied. The development of data transmission networks is a spatial process which stems in large part from settlement factors (the location of nodes and links in the network) as well as from a range of socioeconomic phenomena, such as the existing state of the economy and the social policies currently being pursued.

The classical methods used to construct synthetic indexes in spatial research are: taxonomical indexes, pseudo-monofeature indexes, indicators built on cluster analysis or dendrite analysis, the formal methods of statistics (regression analysis, factor analysis), and potential, i.e. a measure of the intensity of inter-regional influence (Czyż, 2002). Modeling the innovative processes occurring in society in the field of telecommunications (ITC) requires the formulation of certain macroscopic measures, synthesizing the simultaneous variability of the observed parameters of the phenomena studied.

The parameterisation of such IS phenomena in Poland requires the selection of basic (elementary) features – structural and functional properties. Structural (composite) properties describe the constructional features of the observed spatial phenomena. Functional properties concern the operation or use of these elements; they may be described as holistic (approaching the subject as a whole rather than in parts). Both types of properties may be of a quantitative or qualitative nature (Francuz, 1991).

The *network complexity measure* has been proposed as a synthetic, macroscopic measure of the observed phenomena in telecommunications networks. The complexity measure of a network depends on many parameters and is captured in spatial research by measuring entropy in the form of topological network indicators, using indicators of (social) gravitation, using *intervening opportunity* measures, and using space–time measures (Haynes et al., 1999).

The following categories of features have been identified, which at the same time serve as components of the proposed measuring function:

T – technical and technological features (technical network parameters: speed, information transmission volume, signal digitisation),

F – functional features (functions performed, quality and type of information transmitted, data transmission, short text messages, short multimedia messages, speaking clock, etc.),

R – spatial and regional features (coverage, network geometry, topology, and location specifics, such as the lay of the land, forestation, the presence of bodies of water of large surface area, climactic conditions, etc.),

S – socioeconomic features (people's ability to make use of network data – the level of qualifications).

The model of the synthetic measure of network complexity (ΣX) can be denoted as the function:

$$\Sigma X = f(T, F, R, S, \varepsilon) \quad (1)$$

where ε describes random factors.

To evaluate the usefulness of the proposed index in network research, it should be tested, for instance, for compliance with the spatial distribution of another feature of network access. A first approximation at modelling the variability of the synthetic index of ICT network accessibility uses the number of residents in geographical units to model spatial interactions (potential).

2.2. Utilizing the potential model to measure accessibility

Population potential is traditionally understood as a measure of accessibility (cf. Czyż, 2002; Ratajczak, 1999), evaluating the interactions between a specific location and its environment. In telecommunications-related research, population potential can be viewed as the overall capacity of a region to generate interactions in the domain of communications (Werner, 2003). Population potential is measured in terms of number of individuals/km. The istance d_{ij} between the location generating the connection and the target location (straightline distance in km, calculated based on the geographical longitude and latitude of the centres of towns and commune/neighbourhoods, defined at their centroids) expresses the spatial barrier, while P_i expresses the population within the bounds of a given *gmina* (the Polish term for commune/township) (source: BDR (GUS, 2007)), representing the total potential number of individuals who do nevertheless overcome that spatial barrier through transport or communications (*ibidem*). The classical form of the equation for population potential V_i of location *i* (say, a given gmina) is given in (2):

$$V_i = \sum_{\substack{i=1 \\ i \neq j}}^{n} \frac{P_i}{d_{ij}} \quad (2)$$

Network accessibility research can utilize a modified population potential model that is weighted by the rank of the geographical units within a hierarchy, as in equation (3); (Werner, 2003). The spatial distribution of this is shown in Figure 1

$$V_i = \sum_{\substack{i=1 \\ i \neq j}}^{n} \frac{P_i}{d_{ij} h_{ij}} \quad (3)$$

where h_{ij} is an absolute value, corresponding to the difference in rank between the gminas; gminas are ordered by increasing population and given successively numbered ranks.

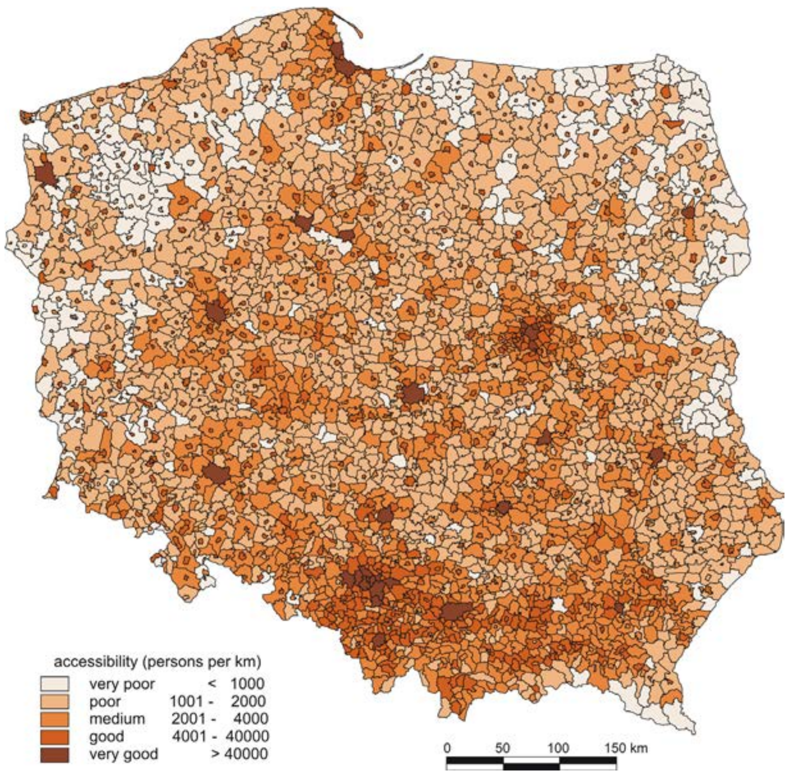

Fig. 1. Network accessibility by *gmina* (commune/township) in Poland, based on a modified population potential model (original results based on GUS data, 2007)

2.2.1. Model verification

The spatial form of the network and its coverage are shaped by such diverse natural, anthropo/geographic, social, and economic factors that the complexity of the problem makes it very difficult to treat analytically (Ratajczak, 1999). One method that enables a solution to be found is called a *Monte Carlo simulation* (Patrykiejew, 1998). A Monte Carlo simulation is based around a physical model of an actually existing phenomenon, expressed in the form of a set of random values. It is a probabilistic model constructed on the basis of a distribution function. Data for the calculated cumulative distribution function is obtained empirically or based on a theoretical model describing the process.

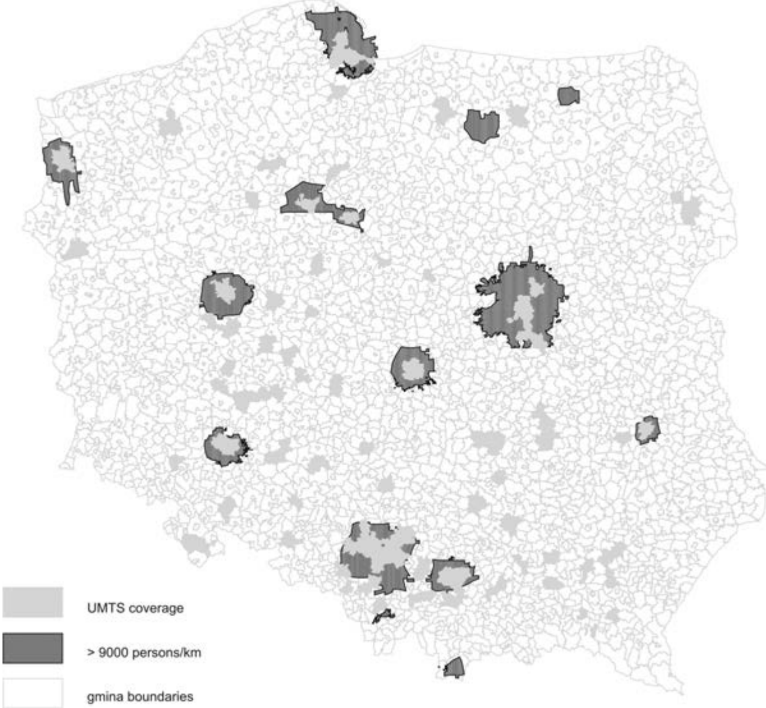

Fig. 2. Simulated modified population potential values (above 9000 persons/km) vs. real UMTS coverage, by *gmina* (commune/township) in Poland

Assuming that the distribution of network users is related to population numbers, we can take this property and the modified population potential index as independent variables. Based on the spatial statistical distribution of the independent variables, we performed a Monte Carlo simulation over Poland's administrative system of gminas. The simulated values of the independent variables, which we can assume are theoretical estimates of the number of network users, were then aggregated within the boundaries of Poland's voivodships (regions) and compared against the observed real numbers of network users, showing Pearson correlation factors of +0.99 (for population number) and +0.83 (for modified population potential). Figure 2 presents a comparison of the simulated modified population potential values to the coverage of UMTS[1] wireless networks in Poland.

2.3. Synthetic indexes

One of the methods for constructing an index is the *synthetic index method* used in what has been called *pseudo-monofeature classification* (Nowak, 2004). The essence of the pseudo-monofeature method lies in constructing a single meta-feature describing the studied set of geographical units, based on a set of different independent measures (simultaneously specifying their nature as stimulating/impeding), by means of statistical procedures, most often operating with standardized values.

Synthetic indexes are mainly used for the linear ordering of multi-feature objects and may serve as the starting point for typological classification. Their interpretation involves evaluating the level of the phenomena described by the independent variables – the higher their value, the higher the value of the synthetic index (Nowak, 2004).

At the same time, in addition to such a complex, synthetic index, some gauge of real network accessibility needs to be worked with. This latter

[1] UMTS – Universal Mobile Telecommunications System

measure should be holistic in nature and be so constructed as to be expressible quantitatively and interpreted qualitatively. One such real measure of accessibility is the number of network users.

The number of network users in a given geographical unit, expressed as an absolute value, may not seem to be an adequate measure of telecommunications accessibility. Instead, this measure should be presented in the form of a relative index, reflecting socioeconomic significance and spatial concentration of the network.

We can identify a range of aspects of network accessibility, and thus formulate a range of features (independent variables describing the composite and functional features of the networks studied). Among other factors, they should reflect the subjectivism in users' evaluation of the usefulness of innovations, personal preferences concerning functionality, and the spatial and temporal aspects, socioeconomic factors, and special regional circumstances.

The proposed synthetic index is essentially a measure of how network accessibility is realized. Our research took the following features into account:

1. Number of Internet users (estimated based on TNS OBOP research);
2. Number of cable television subscribers (source: GUS);
3. Number of fixed-line telephony subscribers (source: GUS);
4. Number of television subscribers (source: GUS);
5. Number of radio subscribers (source: GUS).

Each of the five above-mentioned features can be interpreted as the number of devices in use that may be active in the network (television/radio receivers, fixed line telephones, mobile telephones, computers, or hosts). To bring these categories down to a common denominator, we can define the uniform concept of a „user of a functionally distinct medium." A single individual may make use of all the devices mentioned. Defined in this way, this measure gauges the number of users (in each of the functionally distinct networks: cable television, fixed line telephony, mobile telephony, TV/radio broadcasting, and the Internet). Summing up the individual values yields a value that reflects the number of network users within the given geographical unit.

One frequently used method of defining the significance of a given social phenomenon involves identifying its concentration with respect to the overall population of a geographic unit. In telephony this is known as the *penetration rate,* i.e. the number of subscribers per 100 (or 1000) inhabitants. There is no obstacle to defining the other features in the same fashion.

The other way of constructing a measure of network accessibility involves evaluating spatial concentration, expressed as the mean number of users per 1 km^2. An array of spatial data about the features studied can thus be compiled – because all the features are expressed in the same units, the stage of data standardization can be omitted.

The arithmetic and harmonic means, respectively, of the number of individuals using the individual network devices per 1000 residents by voivodship may be used as synthetic measures, enabling the spatial distribution of network development to be identified.

Developing a synthetic index of telecommunications service accessibility and its spatial depiction over the existing administrative breakdown of the country enables areas with poor infrastructure in this regard to be pinpointed, and at the same time such work may fill in existing gaps in the geographical literature on communications issues and the methodology for studying the development of information society.

The second question that should be asked is whether population potential may also be utilized as a measure of real network access. To answer this, we calculated population potential values (a modified to account for rank-order differences) by voivodship.

To test the possible link between the number of network users by voivodship (with the proviso that such data is absent for mobile telephony) and modified geographical potential values by voivodship, we calculated the Pearson linear correlation coefficient, which came to r = 0.813 (Fig. 3).

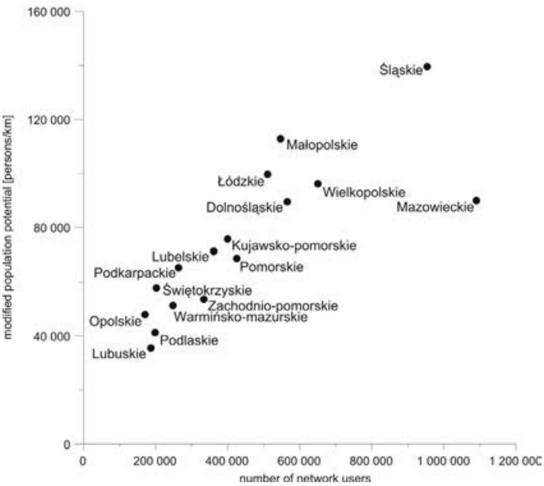

Fig. 3. Modified population potential vs. number of network users, by voivodship (region) in Poland, 2003 (each dot represents one Polish voivodship)

The above facts demonstrate that if data is absent for the real number of network users, the modified population potential model can be used successfully. Instead of the overall population numbers, this model should take account of certain selected demographic characteristics related to the advance of modern civilization, such as the number of individuals who have attained a certain level of education by specific age categories, or the number of individuals employed in innovative sectors of the economy.

We should assume that correlations found on the voivodship level will also obtain on the level of smaller geographical units.

2.4. Indexes and measures of information society

Various indexes and measures of information society have been used in the literature, but there is no consistent methodology. Overviews of the indexes and measures used can be found in the reports of information society research projects, both Polish and European. The measures used were described and analysed in detail in Dziuba (2000); his compilation of measures gauging the informatization of society and the economy includes the *information society index* developed by Japanese scholars from the Research Institute for Telecommunications and Economics – RITE (Dziuba, 2000, citing Ito, 1981). This index encompasses four elements:

1. The amount of information
   - i) number of telephone conversations per person per year,
   - ii) number of periodicals per 100 persons,
   - iii) number of books per 100 persons,
   - iv) population density as a measure of inter-personal communication ,
2. The distribution of communications media
   - i) number of telephones per 100 persons,
   - ii) number of radio receivers per 100 households,
   - iii) number of televisions per 100 households,
3. The quality of information-related activities
   - i) the ratio of service sector employees to the general population,
   - ii) the ratio of students to the overall student-aged cohort,
4. Information ratio
   - i) household spending on information goods and services and information-related activities in relation to all spending.

Another example is the *Information Society Index*, developed by the Boston-based company International Data Corporation (IDC) for the purposes of market research and forecasting. This index is the weighted mean of 23 factors divided into four groups: computer infrastructure, information infrastructure, Internet infrastructure, and social infrastructure, as follows:

1. Computer infrastructure
   - i) number of PCs *per capita,*
   - ii) ratio of PCs to households,
   - iii) ratio of PCs in administration/commerce to non-agricultural workforce,
   - iv) ratio of PCs to the number of students and academic centres,
   - v) percentage of network-connected PCs used outside of households,
   - iv) ratio of software expenditure to hardware expenditure,
2. Information infrastructure
   - i) number of cable network subscribers *per capita,*
   - ii) number of mobile phone users *per capita,*
   - iii) the cost of a telephone call,
   - iv) number of fax users *per capita,*

v) number of radio subscribers *per capita,*
vi) percentage of erroneous telephone calls,
vii) telephone network penetration of households (number of fixed-line telephony subscribers per 1000 households),
viii) number of television subscribers *per capita,*

3. Internet infrastructure
   i) ratio of institutional Internet users to non-agricultural workforce,
   ii) ratio of private Internet users to number of households,
   iii) ratio of internet users to number of students and academic centres,
   iv) ratio of e-commerce sales to number of Internet users,
4. Social infrastructure
   i) number of public libraries,
   ii) newspaper readership *per capita,*
   iii) secondary school enrolment (number of students),
   iv) primary school enrolment.

The *Digital Access Index* – DAI developed by the International Telecommunications Union (ITU), in turn, consists of a range of factors that together, the authors believe, measure the overall ability of individuals in a country to access and utilize information society infrastructure. It is applied on the national and international level for comparative purposes. It is built around five categories, a total of eight „easy to decode" indicators. For comparative purposes, based on overall statistics, four classifications of access to infrastructure and services are delineated: high, upper, medium, and low. ITU specialists believe its construction to be flexible, enabling analysis by gender, country, and over time. The five categories, within which individual indicators are distinguished, are as follows:
– infrastructure,
– affordability,
– knowledge,
– quality,
– use.

The *infrastructure* category includes:
– fixed-line telephony penetration (number of fixed-line telephone subscribers per 100 inhabitants),
– mobile telephony penetration (number of mobile telephone subscribers per 100 inhabitants).

Within the *affordability* category the only indicator is Internet access price, expressed as a percentage of *per capita* income. The *knowledge* category embraces two indicators:
– adult literacy (percentage of individuals able to read and write),
– school enrolment level (percentage of relevant cohort enrolled in school).

Quality of access is also described by two indicators:
– international Internet bandwidth (in bits *per capita*),
– Internet users with broadband access per 100 inhabitants.

This index is calculated as the arithmetic mean of the above five categories, each of them carrying the same weight. Within the individual categories, the individual indicators are also weight evenly (with the exception of the *knowledge* category, where literacy carries 2/3 weight, school enrolment 1/3).

As we have noted, the DAI was introduced for the purposes of international comparison. It is a synthetic index, which while utilizing a uniform methodology describes not just network access but also constitutes a universal gauge of the level of information society, understood as one of the paradigms (doctrines) of the advance of civilization and defined synthetically-descriptively via two characteristics, namely:
1. Universal access among the population to information of general interest or of interest to specific groups of citizens and residents;
2. A level of development and dissemination of data transmission infrastructure and information technologies which enables those technologies to be treated in practice as universal tools and methods of working and participating in business, technical, educational, cultural, and other activity, on both the individual and mass levels.

2.5. The Synthetic Index of Information Society (SIIS)

Developing a synthetic index to gauge the level of development of information society makes sense particularly when we want to relate the phenomenon under study to specific geographical units. Comparing the spatial distribution of the value of such an index on a voivodship-by-viovodship basis may illustrate the gaps between Poland's regions in terms of IS development.

The principles defining the synthetic DAI index were largely adopted in order to formulate an analogous synthetic measure of the level of IS development definable over Poland's voivodships. Our Synthetic Index of Information Society (SIIS) is thus constructed as follows:

$$SIIS = \frac{1}{n}\sum_{i,j} H_{ij}$$

$$H_{ij} = \frac{x_{ij} - x_{ij\,\min}}{x_{ij\,\max} - x_{ij\,\min}}$$

where

H_{ij} denote partial indicators, representing

– infrastructure: fixed-line telephony penetration (number of subscribers per 1000 inhabitants),
– knowledge: school attendance level[2] (for middle schools and primary schools, in %),
– use: Internet subscribes, Internet subscribers per 1000 residents,
– other: index of urbanization, *per capita* GDP,

i – a region, the basic geographic unit of the study,
j – a component variable,
x_{ij} – value of the given variable in the given region.

[2] The ratio of individuals enrolled (as of the start of the school year) in a given level of education (regardless of age) to the population (as of 31 Dec) of the relevant age cohort for that level of education. For example, the school enrollment indicator is calculated on the primary school level by dividing the number of all pupils enrolled in primary schools, regardless of their age, as of the start of the given school year, by the number of individuals in the population aged 7-12 (the cohort associated with this level of schooling) as of 31 December of the same year; the outcome is expressed as a percentage. http://www.stat.gov.pl/gus/definicje_PLK_HTML.htm?id=POJ-5063.htm

Due to a lack of available data and a lack of spatial differentiation for certain indicators, only 3 of the indicators were carried over from the DAI methodology, namely *infrastructure, knowledge,* and *use*. Our index additionally takes account of the spatial differentiation of information society in Poland by including the indicators of *urbanization by voivodship*, and per capita *GDP by voivodship.*

Table 1. SIIS for Poland

Category	Variable	Value for voivodships			Index for voivodship	
Infrastructure	Fixed-line telephony penetration by viovodship	min	249		0.00	
		max	391		1.00	
		mean	319		0.50	
Knowledge	School attendance level by viovodship		middle school	primary school	middle school	primary school
		min	93.2	95.8	0.00	0.00
		max	110.5	104.8	1.00	1.00
		mean	101.0	100.0	0.45	0.46
Use	Internet subscribers by viovodship	min	75 550		0.00	
		max	2 530 927		1.00	
		mean	786 980		0.29	
	Internet subscribers per 1000 residents by viovodship	min	20		0.00	
		max	150		1.00	
		mean	63		0.33	
Other	Urbanization index by viovodship	min	40.36%		0.00	
		max	8.65%		1.00	
		mean	60.05%		0.51	
	Per capita GDP by viovodship	min	15565		0.00	
		max	34179		1.00	
		mean	20292		0.25	

Data for mobile phone penetration broken down by voivodship is not available, and thus such penetration was not included in our index. Affordability was left out as well, because the rates charged by broadband operators are similar throughout Poland and vary in terms of the bandwidth of the data channel for downloading to the user. The *knowledge* category was applied in Poland with only one component indicator, school enrolment. The *use* category was posed in terms the number of Internet users by voivodship based on data obtained from Gemius Traffic studies (Gemius Traffic, 2006).

According to the third report on the monitoring of EU candidate countries in terms of the telecommunications sector dated 16 June 2003, drawn up by IBM for the European Commission, Internet penetration then reached 23% in Poland, meaning 8.8 million Internet users, with the most in the Mazowieckie Voivodship followed by the Śląskie Voivodship.

According to the report's authors, large differences are visible in Internet use across the individual voivodships (regions) (Fig. 4). A significant number of Internet users reside in the Mazowieckie, Śląskie, Wielkopolskie, Dolnośląskie, Małopolskie and Pomorskie Voivodships, i.e. those regions with the highest level of development and the highest *per capita* GDP. The other voivodships, especially the very poor ones, are characterized by small numbers of Internet users. These differences derive from the level of development in the voivodships and the affluence of the given regional populations. In each case, the most important element is price. Analogous results were obtained in the Gemius Traffic studies in 2005 and 2006.

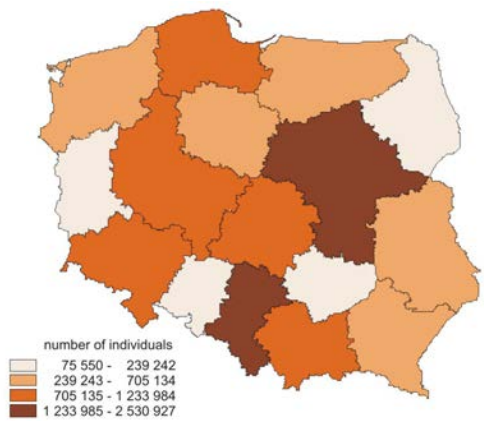

Fig. 4. Number of Internet users by voivodship (2003)

Table 2. Internet users by voivodship (2003 – 2006), based on OBOP and Gemius research

Voivodship	Code	Internet users per 100 residents in 2003 (OBOP)	Population	Area [km2]	Internet users in 2003 (OBOP)	Internet users in 2003 [%] (Gemius)	Internet users in 2003 (Gemius)	Internet users in 2006 [%] (Gemius)	Internet users in 2006 (Gemius)
Dolnośląskie	2	80	2 898 534	19 948	231 883	10.62	932 955	8.00	1 007 334
Kujawsko-pomorskie	4	70	2 070 529	17 970	144 937	4.23	371 601	4.40	554 034
Lubelskie	6	60	2 202 473	25 114	132 148	4.05	355 788	5.60	705 134
Lubuskie	8	30	1 009 110	13 989	30 273	2.70	237 192	1.20	151 100
Łódzkie	10	50	2 605 393	18 219	130 270	5.37	471 749	6.70	843 642
Małopolskie	12	100	3 233 636	15 190	323 364	7.71	677 315	8.80	1 108 067
Mazowieckie	14	150	5 118 253	35 579	767 738	19.47	1 710 418	20.10	2 530 927
Opolskie	16	40	1 057 544	9 412	42 302	1.98	173 941	1.00	125 917
Podkarpackie	18	40	2 107 319	17 844	84 293	4.83	424 310	3.50	440 709
Podlaskie	20	40	1 209 276	20 180	48 371	2.93	257 397	1.90	239 242
Pomorskie	22	60	2 180 013	18 293	130 801	6.52	572 775	6.50	818 459
Śląskie	24	110	4 720 680	12 331	519 275	11.96	1 050 673	14.30	1 800 610
Świętokrzyskie	26	20	1 303 391	11 691	26 068	1.61	141 437	0.60	75 550
Warmińsko-mazurskie	28	40	1 433 427	24 203	57 337	2.72	238 949	2.90	365 159
Wielkopolskie	30	80	3 351 544	29 826	268 124	9.53	837 200	9.80	1 233 984
Zachodnio-pomorskie	32	30	1 694 055	22 896	50 822	3.77	331 190	4.70	591 809

Note that access is described on the one hand in terms of infrastructure, and on the other hand in terms of user capabilities: level of education, affluence.

The Synthetic Index of Information Society (SIIS) was thus defined based on the above-described set of indicators, and its spatial distribution is illustrated in Figure 5.

The first step in calculating the SIIS was to normalize each of the indicators to a range of <0;1>. Next the synthetic index was constructed as the arithmetic mean of the individual normalized indicators. The next step was to correlate the population potential values by voivodship with the SIIS values. The highest correlation for the voivodship level is seen for SIIS and rank-weighted population potential (0.659).

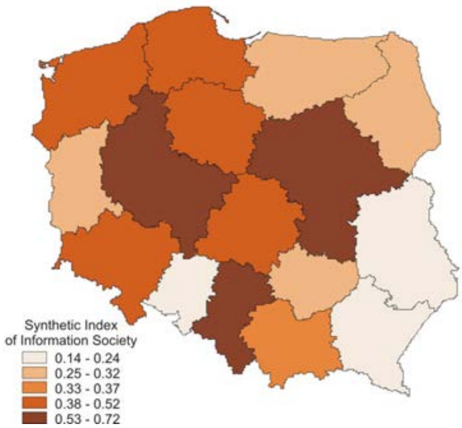

Fig. 5. Spatial distribution of the Synthetic Index of Information Society (SIIS)

The number of Internet users shows the highest correlation with population numbers and the number of fixed-line phone subscribers. The modified population potential shows the highest correlation with: population density (0.89), the number of phone lines (0.86), the number of Internet users (0.83), and population number (0.82).

(Modified) population potential is also highly correlated – at above 0.8 – with population number, number of Internet users, number of main and standard telephone lines, and also with population density (spatial concentration). It also shows a significant correlation with SIIS (0.66).

For smaller geographical units, a higher coefficient of correlation with SIIS is observed for the weighted population potential. For the aggregated values on the voivodship level, the classical population potential index approximates the SIIS values better.

Closing Remarks

One of the most important factors for the spatial positioning of telecommunications networks is population distribution. As a starting point for evaluating network development, we developed a (modified) population potential model and verified it – comparing it against the Synthetic Index of Information Society separately for voivodships and gminas. This approach abstracts away from the situation of many entities operating on the telecommunications market.

It is important to identify where telecommunications infrastructure is present and what its coverage is. That is why the degree of interaction between individual network nodes needs to be evaluated. One of the parameters that may affect where a given node is positioned is its link to the size of the population residing in the given area. Evaluations were calculated in consideration of the population potential of a given region. The database included information about the demographic structure of the population actually residing in the individual gminas, as of 31 December 2003, assuming that this group in practice constitutes the users of network operators.

Comparison of the spatial distribution in the Synthetic Index of Information Society (SIIS) and the values for modified population potential has shown it is possible for the latter to be substituted for the SIIS, especially in situations when there is a lack of statistical data, precluding the SIIS's component indicators from being evaluated for very small geographical units. The fact that such substitution is possible for the modified population potential model verifies the hypothesis that the process of developing IS technology is performed based on a hierarchical, spatial diffusion of innovations.

Developing statistical tools to describe IS represents a long-term process, demanding the solution of many problems in terms of classification issues, source data quality, and measurement tools. It is a kind of paradox that despite the ever-increasing quantity of information and the increasingly broad and rapid access to it, we still know relatively little about the society that is being shaped by the impact of this information. The judicious application of statistical tools and mathematical models may help close this information gap regarding IS. In particular, this objective may be served by the use of the component partial indicators and the synthetic SIIS index proposed and developed herein.

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Przestrzenne zróżnicowanie stopnia rozwoju społeczeństwa informacyjnego w Polsce

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Streszczenie. W artykule przedstawiono istotne czynniki rozwoju społeczeństwa informacyjnego (SI) w Polsce, wskaźniki charakteryzujące stan i dynamikę procesu tworzenia SI oraz opisano metodykę postępowania badawczego. Założono, że ważnym czynnikiem rozwoju SI jest szeroko rozumiana dostępność sieci. Sformułowano następującą hipotezę: zmodyfikowany (uwzględniający różnice kolejności - rangę oraz charakterystyki demograficzne jednostek przestrzennych) wskaźnik potencjału ludnościowego jest odpowiednią miarą dostępności sieci, a tym samym pozwala wnioskować o poziomie rozwoju SI. Hipoteza została zweryfikowana na podstawie danych dla województw. Opracowano syntetyczny miernik SI (MSSI), którego konstrukcja opiera się na wskaźnikach cząstkowych. Dokonano korelacji miernika syntetycznego i poszczególnych wskaźników cząstkowych z klasycznym i zmodyfikowanym potencjałem ludnościowym. Na podstawie światowej i polskiej literatury przedmiotu wybrano wskaźniki cząstkowe, dla których możliwe było zebranie danych statystycznych przydatnych do budowy syntetycznego miernika SI. Szczególną uwagę zwrócono na przestrzenną dywersyfikację stopnia rozwoju SI.

Słowa kluczowe: model potencjału ludnościowego, społeczeństwo informacyjne