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REGIONAL DEVELOPMENT AND COMMUNICATION NETWORKS: A CASE STUDY OF WESTERN UKRAINE

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ABSTRACT

Motives: Communication is the basis of existence of modern civilization. Nowadays, communication is part of the most intensive innovation processes. The level of formation of communication networks largely determines both the preconditions and the current development of regions.
Aim: The aim of the study was to analyze the interdependencies between the level of socio-economic development of the examined areas and the formation of communication networks on the example of local territorial units of Western Ukraine.
Results: The correlation analysis revealed significant links between communication networks and regional development. It is not always possible to determine the exact cause and effect in a specific case. The results of this study indicate that the socio-economic development of Western Ukraine has a more significant impact on the functioning of communication networks than the communication networks have on the socio-economic development. Like other natural and socio-economic resources, the presence of communication networks is a prerequisite for the development of the region. The emergence, perception and widespread use of new communications depend on several factors, one of which is the socio-economic development of a given area.

Keywords: communication networks, transport networks, cellular networks, social networking services, migration networks, Western Ukraine

INTRODUCTION

The interaction between human individuals and communities is the basis for the functioning of society. This interaction manifests itself in various ways, from communication to migration. The entire human history is a history of interactions between individuals and social groups of different sizes.

To grasp and display the spatial aspects of the uneven population, economy, and resource distribution, understanding the functioning of communication networks and the factors influencing their

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development in a specific location and time is crucial. For example, information about areas with neglected roads, inefficiently functioning public transport, weak cellular network signal, no 4G coverage, no Internet etc. has important value.

Territory-wise, the communication networks are geographical complexes formed by a multitude of various economic, social, and natural counterparts. For the functioning of each one, the spatial component is important (Puhach, 2021).

Nowadays, introducing innovations in communications is at its peak. New technologies are emerging: high-speed trains create competition for air transport; Wi-Fi technology has taken a big step toward the development of communications; 5G mobile connection will create competition for the wired Internet, making us even more "mobile"; new services constantly appear in the social network services (SNSs) market. The sharing economy ideas (BlaBlaCar, Uklon, Uber, Bolt services) are gaining immense popularity among car owners. Even relatively stable migration networks can undergo radical changes if needed. Therefore, the vector of labor migration in Ukraine has transformed remarkably from the eastern (Russia) to the western (EU countries) after 2014 (Fedyuk & Kindler, 2016; Sadova, 2019). That is, changes are occurring in all major types of communication networks. Therefore, scholars and practitioners should keep abreast of changes in communication networks.

To manage the communication networks, you need to have the information about them, understand their complexity and interconnections, and have practical skills in their effective use. The analysis of communication networks is a scientific basis for the development of forecasts, programs, and plans for regional socio-economic development in order to create better living conditions for the population.

The aim of our research is to analyze the interdependencies between the level of socio-economic development of areas and the formation of their communications by the example of local territorial units of Western Ukraine.

At the beginning of the study, we formulated three working hypotheses:

1. The first hypothesis states that regional economic development has a greater impact on the level of communication networks than networks on economic development.
2. The second hypothesis states that the level of communications development, especially new ones (social network services), can be an indicator of the socio-economic development.
3. The third hypothesis states that the large cities are communication focal points, i.e., they have a vastly superior communication network than rural peripheral areas.

LITERATURE REVIEW

The problems of communications and regional development have arisen great interest among researchers in the past and in the present. Some researchers have noted the strong impact of various types of communications on the level of regional development (Hrytsevych & Senchuk, 2010; Khanna, 2016; O'Dell & Richards, 1971; Puhach & Mezentsev, 2021; Rodrigue, 2020; Schmidt & Cohen, 2013; Strelko at al., 2023; Urry, 2007; etc.).

Thus, Khanna (2000) defends that communications are more critical for the contemporary world than state borders. The well-known saying "Geography is destiny", according to P. Khanna, is losing relevance. The long-standing beliefs that climate and culture dictate the fate of societies and that the small countries depend forever on larger ones are no longer relevant. Thanks to global communication networks (highways, railways, airports, pipelines, power grids, Internet cables, etc.), a new aphorism will appear – "The connectivity (infrastructure) is a destiny".

The development of communications at the regional and local levels determines the possibility of connecting to "global connectivity" and "supply chains". The areas with better communication networks are more likely to stay aware of today's globalized economy than isolated areas. Regarding Western Ukraine, the standout positive point in the

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context of Russian invasion is a distinctly expressed pro-European (and therefore global) vector of development. When it comes to interaction, Western Ukraine prioritizes Europe over Russia and Asia.

In 1994, an unprecedented experiment was carried out in Northern England. The villages tried to conduct a high-speed (at that time) Internet to identify the impact of communications on the development of rural areas (Ray & Talbot, 1999). The experiment was based on the "Rebirth of the Local" and "Post--Fordism" concepts. The experiment immediately encountered obstacles: rural residents and businesses were not psychologically/culturally ready to use the Internet potential; the local population was underequipped with computers; the telecommunications infrastructure was much less developed compared to the one in the cities. A rural economy with a small population and inconvenient geographical location made these areas unattractive for telecommunications providers. The study's conclusion noted that telematics "has the potential to increase competitiveness and improve for the Rural North" (Talbot, 1997).

Schmidt and Cohen (2013) noted that the successful potential opportunities of cellular networks and social network services for radical societal changes. It can be seen how the rapid spread of the Internet and smartphones in Africa is reshaping the continent's everyday life. The authors acknowledge the significant opportunities presented by smartphones in resolving socio-economic challenges across various sectors, such as education, medicine, business, and self-employment. Smartphones can help to reduce social tensions and mitigate the impact of unfavourable natural disasters.

GSMA (in German: Groupe Speciale Mobile Association), which unites around 750 global mobile operators and 400 companies related to mobile connection in 220 countries, states that the development of cellular networks contributes to implementing all 17 UN Sustainable Development Goals (GSMA, 2023a). This is due to the "GSMA Mobile for Development" programs (GSMA, 2023b), thereby stimulating innovation in digital technologies to reduce inequality and launching numerous essential initiatives.

Numerous studies explore how communication networks affect regional development in different countries. In central and eastern European countries, strong connections exist between transport development and regional development. We can observe similar spatial patterns in Poland (Komornicki & Szejgiec-Kolenda, 2023; Ogryzek & Wolny-Kucińska, 2021; Rokicki & Stępniak, 2018), Lithuania (Griškevičiūtė--Gečienė & Griškevičienė, 2016), Romania (Marin & Olaru, 2015), Slovakia (Masárová & Ivanová, 2016), Hungary (Tóth, 2009), such as:

- the road network in all the countries is dense enough, but there is a low share of motorways and expressways;
- the presence of road infrastructure in the regions (NUTS-2 and NUTS-3) is very uneven;
- only a harmonious development of all transportation modes and collaboration between them can finally ensure the economic development;
- the existence of a high demand for transport development which makes it difficult to finance them;
- the excessive development of the transport network is not conducive to environmental protection, and therefore future measures in transport development should be more environmentally friendly (Ogryzek & Wolny-Kucińska, 2021);
- a developed transport infrastructure is an important prerequisite for the functioning of the economy of each state and helps to reduce disparities between the regions;
- improving the level of road infrastructure in countries and regions presents new opportunities for the growth of tourism, the inflow of foreign investments, and higher levels of employment, thereby supporting the overall economic and social development (Masárová & Ivanová, 2016);
- the strategic development of transport systems is defined by multiple different factors and indicators that must be evaluated in the territorial planning documents (Griškevičiūtė-Gečienė & Griškevičienė, 2016);
- transport infrastructure investments seldom have a significant impact in urban areas while in rural

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areas, this impact is very noticeable (Rokicki & Stępniak, 2018).
– the opening of new motorway sections will, to a minor extent, contribute to the fundamental changes in the directions of traffic flows. Noticeable changes will apply in the regions without a developed network of motorways (Kowalski & Wiśniewski, 2019).

Social networks have a much greater impact on regional development than it might seem at first glance. Significant is the data analysis of Facebook in the United States by economists from Harvard, Princeton, and New York universities (Bailey et al., 2018) showing that online social networks can shape various aspects of social and economic activity: migration and trade, job-seeking, innovation, consumer preferences, and sentiment, public health, social mobility, and more. Social connectedness, in fact, repeats the contours of administrative-territorial divisions, and virtual connections are mostly a duplication of communications in the real world. The existing theoretical work suggests that the diversity of social networks is an important determinant of economic development. Conversely, tightly clustered social ties may be a sign of a low development level. The geographic dispersion of friendship links across US counties is highly correlated with social and economic outcomes at the county level, such as average income, educational attainment, and social mobility though these correlations cannot be interpreted as causal (Bailey et al., 2018).

Also, we have found the empirical researches showing the relationships between the diversity of cellphone networks and regional economic development (Eagle et al., 2010), documenting that social networks play an important role in facilitating migration by providing the information as well as social and economic support (Munshi, 2016), presenting evidence on the impact of an expansion in mobile telephony and broadband Internet services on economic development at the subnational level (Mensah, 2021).

The communication networks of Western Ukraine have different degrees of study. A wide range of papers explore the transport network and population migration.

For instance, Hrytsevych and Senchuk (2010) studied the road transport network in the context of European integration, the curvature of the motor vehicle space (Hrytsevych & Senchuk, 2011b), poly highways (a combination of road and rail transport on a particular section) of the Carpathian region of Ukraine (Hrytsevych & Senchuk, 2011b), historical and geographical features of the development of the railway network in the Western region of Ukraine (Hrytsevych & Senchuk, 2008). Pikulyk (2009) analyzed the spatial aspects of transport infrastructure for the socio-economic development in the Western region of Ukraine. Senkiv (2016) shaped the geologistical characteristic of the Western region of Ukraine. In particular, she analyzed the road and railway networks using graph theory and GIS modeling (Senkiv, 2017).

The migrations study in Ukraine has a long tradition. The researchers of the migration processes in Ukraine are: Fedyuk and Kindler (2016), Jóźwiak and Piechowska (2017), Malynovska (2018), Pozniak (2007), Rovenchak and Volodko (2015), Sadova (2019), Zapadniuk (2011), and others. However, these works consider Ukraine either as a whole or at the macro level in terms of administrative regions.

On the contrary, the spatial aspects of the development of cellular networks received scarce attention. These papers exemplify an economic nature, which definees Ukraine without internal differences taken into consideration. Among the scientific studies with a clear spatial approach, we can mention the study of domestic tourism in Ukraine, based on mobile data (Kyivstar, 2020), the analysis of territorial differences in Kyivstar network coverage in Western Ukraine (Puhach et al., 2022).

A similar situation is observed in the study of social network services. The analytical report "Facebook and Instagram in Ukraine (January 2023)" (Plusone, 2023) is devoted to the spatial aspects of social online media in Ukraine. Puhach and Mezentsev (2021) analyzed

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the peculiarities of Facebook distribution in Western Ukraine. Puhach et al. (2021) studied the features of social media use among the number of students in Western Ukraine.

Despite the large number of studies, we have yet to find scientific papers which comprehensively investigate various communication networks of Western Ukraine in their relationship with the level of socio-economic development at the local level. It emphasizes the relevance of our study once again.

MATERIALS AND METHODS

Our study area is Western Ukraine (Volynska, Zakarpatska, Ivano-Frankivska, Lvivska, Rivnenska, Ternopilska, and Chernivetska oblasts). These regions became part of Ukraine only after 1939. The population of these territories actively supports the European vector of Ukraine's policy and implements intensive communications with the EU countries. All this forms a unique socio-economic, cultural, and political situation, which is reflected in the development of communication networks.

In our study, among the number of numerous/various communication networks, we analyzed the following main communication networks: transport (road and rail), cellular networks (3G and 4G mobile operators Kyivstar, Vodafone, Lifecell), social networking services (Facebook, Instagram), and migration networks (Fig. 1). They are the ultimate representation of the entire whole. The basic units of the study are raions and cities of regional subordination (the administrative-territorial units of the 2nd level in Ukraine).

To analyze the level of development of communication networks in Western Ukraine, we used our

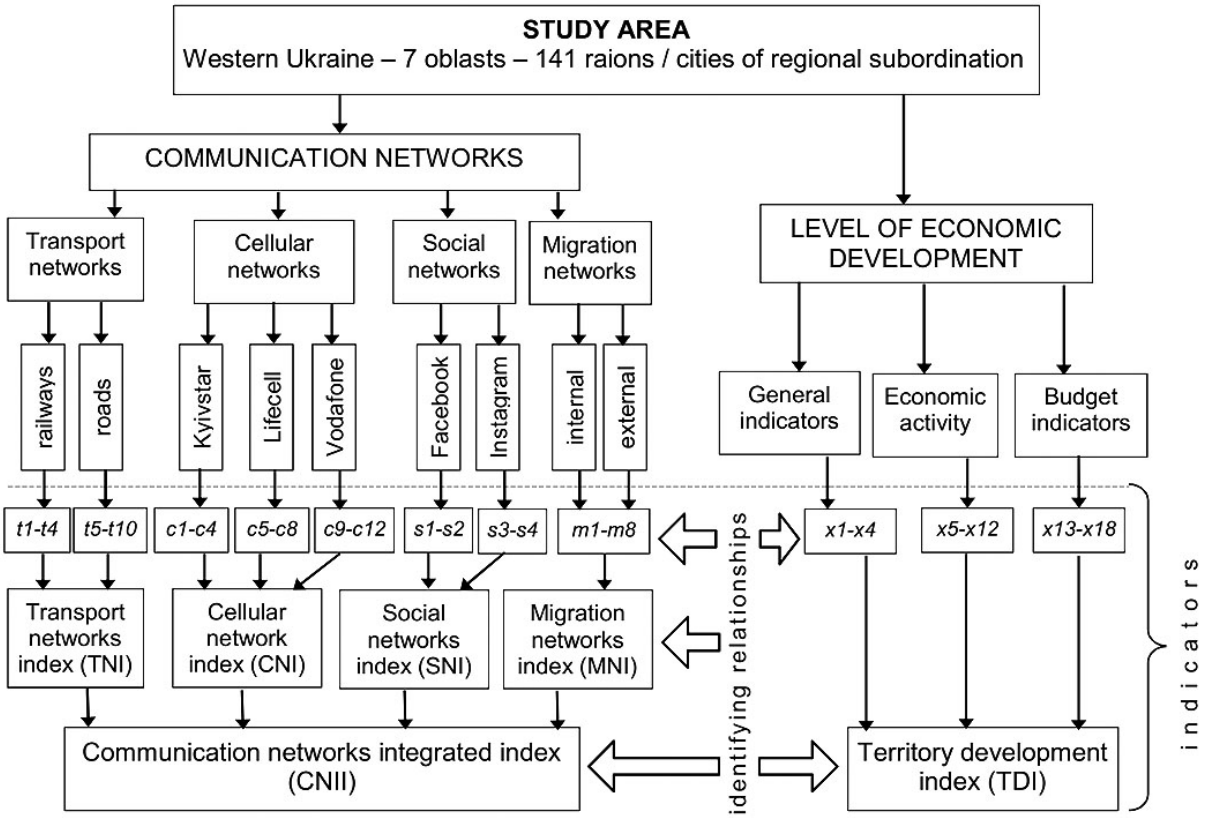

Fig. 1. The research scheme
Source: authors' elaboration.

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proposed *communication networks integrated index* (*CNII*), which comprises 4 block indices:

$$CNII = TNI + CNI + SNI + MNI, \quad (1)$$

where *CNII* stands for the communication networks integrated index, *TNI* stands for the transport networks index, *CNI* denotes the cellular network index, *SNI* denotes the social networks index, and *MNI* corresponds to the migration networks index.

The block indices (*TNI, CNI, SNI, MNI*) were calculated as the arithmetic mean of the standardized indicators.

The transport networks index (*TNI*) was calculated by the following formula:

$$TNI = (t1 + t2 + t3 + t4 + \ldots + t10)/10, \quad (2)$$

where *TNI* stands for the transport networks index, *t1* stands for the length of railways (km), *t2* denotes the railways density (km/1000 sq. km), *t*3 denotes the Engel's coefficient for railways, *t4* denotes the length of roads (km), *t*5 represents the density of roads (km/1000 sq. km), *t6* shows the for Engel's coefficient for the roads, *t7* shows the volume of goods transported by automobile transport (thousand tons), *t8* is the volume of goods transported by automobile transport (tons/person), *t9* is the turnover of automobile transport (million tkm), and *t10* stands for the turnover of automobile transport (tkm/person).

Since different roads have different importance for the development of the territory, we have conducted the normalization procedure for indicator *t4*. During normalizing, the following weight coefficients were used for different classes of roads: trunk – 1.25, primary – 1.25, secondary – 1.0, tertiary – 0.75, unclassified – 0.75. Indicators *t5* and *t6* were calculated based on the normalized indicator *t4*.

The cellular network index (*CNI*) was calculated by the following formula:

$$CNI = (c1 + c2 + c3 + c4 + \ldots + c12)/12, \quad (3)$$

where *CNI* represents the cellular network index, *c1* represents the coverage area of 3G Kyivstar network (sq. km), *c2* represents the share of territory covered by 3G Kyivstar (%), *c3* denotes the coverage area of 4G Kyivstar network (sq. km), *c4* denotes the share of territory covered by 4G Kyivstar network (%), *c5* stands for the coverage area of 3G Lifecell network (sq. km), *c6* stands for the share of territory covered by 3G Lifecell network (%), *c7* is the coverage area of 4G Lifecell network (sq. km), *c8* denotes the share of territory covered by 4G Lifecell network (%), *c9* shows the coverage area of 3G Vodafone network (sq. km), *c10* shows the share of territory covered by 3G Vodafone network (%), *c11* is the coverage area of 4G Vodafone network (sq. km), and *c12* represents the share of territory covered by 4G Vodafone network (%).

The social networks index (*SNI*) was calculated by the following formula:

$$SNI = (s1 + s2 + s3 + s4)/4, \quad (4)$$

where *SNI* represents the social networks index, *s1* denotes the number of Facebook users (people), *s2* denotes the Facebook penetration rate (%), *s3* denotes the number of Instagram users (people), and *s4* shows the Instagram penetration rate (%).

The migration networks index (*MNI*) was calculated by the following formula:

$$MNI = (m1 + m2 + m3 + m4 + \ldots + m8)/8, \quad (5)$$

where *MNI* stands for the migration networks index, *m1* stands for the number of arrivals (people), *m2* stands for the number of departures (people), *m3* is the population migration balance (people), *m4* is the volume of population migration (people), *m5* is the number of arrivals (per 1000 people), *m6* is the number of departures (per 1000 people), *m7* defines the population migration balance (per 1000 people), and *m8* shows the volume of population migration (per 1000 people).

To determine the level of socio-economic development of the territories and compare it with the level of communications development, we used our proposed *territory development index* (*TDI*), which was calculated by the following formula:

$$TDI = x1 + x2 + x3 + x4 + \ldots + x18, \quad (6)$$

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where *TDI* stands for the territory development index, *x1* stands for the area (sq. km), *x2* represents the population (people), *x3* represents the population density (people /sq. km), *x4* denotes the urbanization level (%), *x5* denotes the number of legal entities (units), *x6* denotes the number of legal entities (units per 1000 people), *x7* is the volume of sales by legal entities (thousand UAH), *x8* is the volume of sales by legal entities (UAH per 1 person), *x9* shows the number of individual entrepreneurs (units), *x10* is the number of individual entrepreneurs (units per 1000 people), *x11* is the volume of sales by individual entrepreneurs (thousand UAH), *x12* represents the volume of sales by individual entrepreneurs (UAH per 1 person), *x13* represents the revenues of local budgets (UAH), *x14* denotes the revenues of local budgets (UAH per 1 person), *x15* defines the expenditures of local budgets (UAH), *x16* defines the expenditures of local budgets (UAH per 1 person), *x17* denotes the deficit (-) / surplus (+) of local budgets (UAH), and *x18* denotes the deficit (-) / surplus (+) of local budgets (UAH per 1 person).

We use the average values for 2016-2020 in order to avoid fluctuations in indicators by years. To make the indicators comparable for further analysis, the data were normalized.

The following primary data were taken: the lengths of roads and railways (indicators *t1*, *t4*) from the thematic layers of the open mapping service OpenStreetMap (Geofabrik, 2021); the area covered by cellular networks (indicators *c1*, *c3*, *c5*, *c7*, *c9*, *c11*) from the MobUA.net (2021). To determine the number of social media users (indicators *s1*, *s3*), we used the targeting function (AdEspresso, 2023; Facebook, 2021). All other primary indicators (indicators *m1*, *m2*, *m3*, *m4*, *x1*, *x2*, *x5*, *x7*, *x9*, *x11*, *x13*, *x15*, *x17*) were obtained from the State Statistics Service of Ukraine (2021) and its territorial subdivisions.

A variety of methods were applied, such as comparative geographical analysis, statistical analysis, mapping, time series approach, correlation analysis, GIS methods, and techniques to study the relationships between regional development and communication networks. The GIS software package QGIS Desktop 3.16 performed spatial analysis and computation.

RESULTS

Assessment of the level of communication networks development

We used the *communication networks integrated index* (CNII) to analyze the level of the communication networks development in Western Ukraine. The maximum value of CNII, which significantly exceeds other areas, is observed in the city of Lviv (CNII = 2.469). This is the largest socio-economic, cultural, political and communication center of Western Ukraine, which connects with other regional centers by transport routes of the highest quality. The following cities in the ranking are the regional centers of Ivano-Frankivsk, Ternopil, Chernivtsi, Rivne, Lutsk (CNII is from 1.791 to 2.057). They are the focal points of communications in their oblasts. Pustomytivskyi raion (CNII = 1.742), which is adjacent to Lviv and is part of the Lviv agglomeration, is similar to regional centers. Zakarpattia cities of Mukachevo (1.652) and Uzhhorod (1.573) have similar indices. Zakarpatska oblast is the only one with no clear dominance of one center. Mukachevo City has a slightly higher index due to its more central position in the oblast (Fig. 2). This confirms the third hypothesis of our study.

A high CNII (1.200–1.536) is particular for the following large cities, which are powerful communication hubs: Berehovo, Chervonohrad, Chop, Chortkiv, Drohobych, Dubno, Kalush, Kolomyia, Kovel, Kremenets, Morshyn, Novodnistrovsk, Ostroh, Sambir, Stryi, Varash, Volodymyr. As well as it refers to Kovelskyi, Lutskyi (Volynska oblast), Vynohradivskyi, Irshavskyi, Uzhhorodskyi (Zakarpatska oblast), Buskyi, Horodotskyi, Zhydachivskyi, Zhovkivskyi, Sokalskyi, Yavorivskyi (Lvivska oblast), Dubenskyi, Rivnenskyi, Sarnenskyi (Rivnenska oblast), Ternopilskyi (Ternopilska oblast) raions (Fig. 2). All these areas either border with regional centers (Lutskyi, Uzhhorodskyi, Horodotskyi, Zhovkivskyi, Yavorivskyi, Rivnenskyi, Ternopilskyi raions), or with large cities, namely

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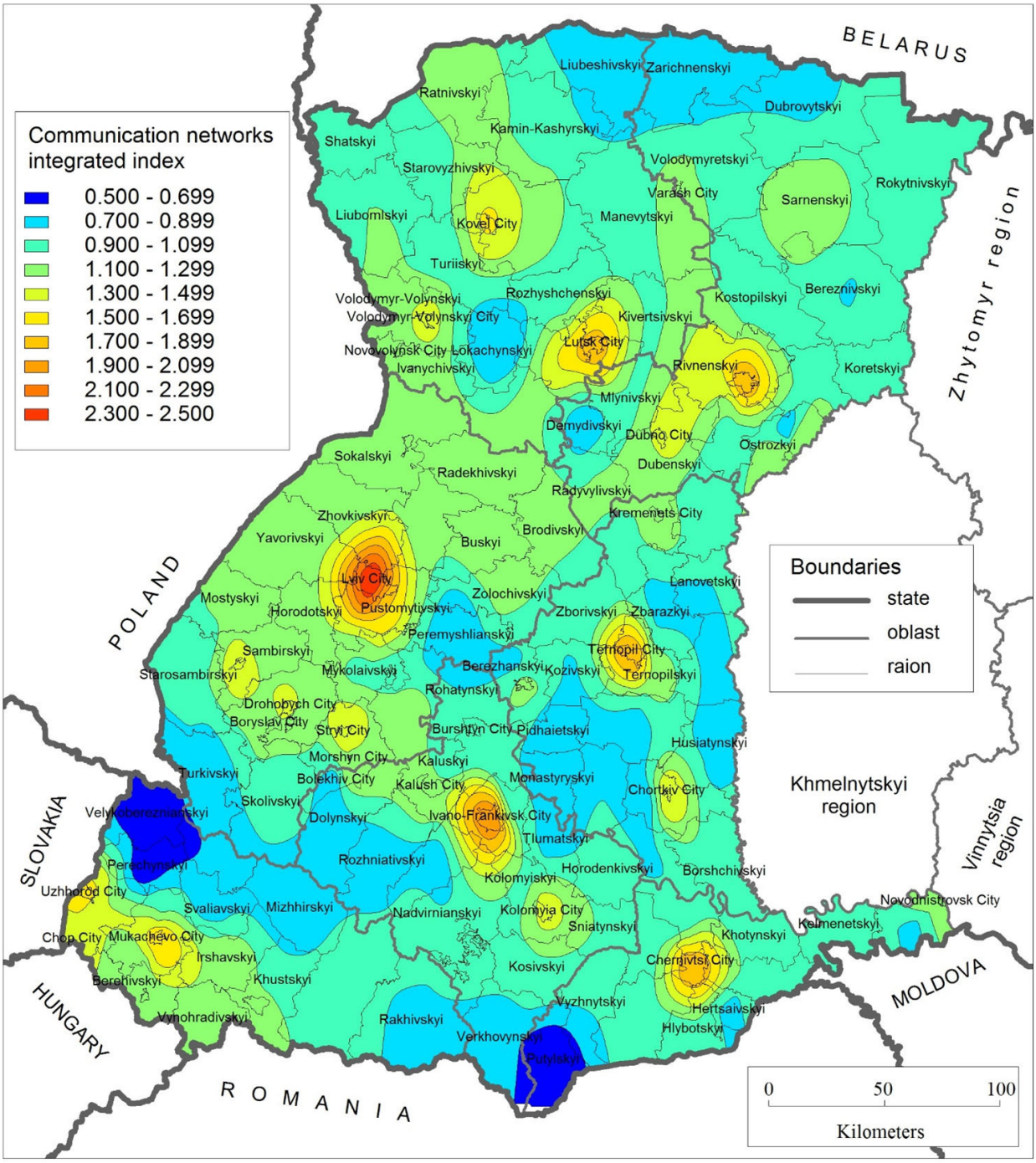

Fig. 2. Communication networks integrated index in Western Ukraine
Source: own preparation based on data from Facebook, OpenStreetMap and State statistics services of Ukraine.

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powerful transport hubs (Kovelskyi, Sokalskyi, Dubenskyi raions), or they have convenient geographical location (Vynohradivskyi, Irshavskyi, Buskyi, Zhydachivskyi, Sarnenskyi raions). This once again confirms the third hypothesis of our study.

The minimum values of CNII (less than 0.900) are typical for the area of the Bolekhiv City Council (due to the large rural territories belonging to the City Council area), as well as Lokachynskyi, Liubeshivskyi (Volynska oblast), Volovetskyi, Mukachivskyi, Rakhivskyi, Svaliavskyi (Zakarpatska oblast), Bohorodchanskyi, Verkhovynskyi, Dolynskyi, Rozhniativskyi, Tlumatskyi (Ivano-Frankivska oblast), Peremyshlianskyi, Turkivskyi (Lvivska oblast), Bereznivskyi, Demydivskyi, Dubrovytskyi, Zarichnenskyi, Ostrozkyi (Rivnenska oblast), Berezhanskyi, Buchatskyi, Husiatynskyi, Zalishchytskyi, Zbarazkyi, Kozivskyi, Lanovetskyi, Pidvolochyskyi, Pidhaietskyi, Terebovlianskyi, Chortkivskyi (Ternopilska oblast), Hertsaivskyi, Sokyrianskyi (Chernivetska oblast) raions (Fig. 2). Administrative raions with the lowest CNII are often characterized by peripherality within oblasts. Many of them are clearly identified as raions with agrarian specialization (a large number of raions of Ternopilska oblast), or have mountainous terrain. Some raions are adjacent to the small cities of regional subordination (Ostrozkyi, Berezhanskyi, and Chortkivskyi raions). In this case, a raion does not have its own "center", and all socio-economic activities and communications are concentrated in these cities.

We recorded particularly low rates of CNII (less than 0.600) in Velykobereznianskyi (0.591) and Perechynskyi (0.536) raions of Zakarpatska oblast and Putylskyi raion (0.571) of Chernivetska oblast. These are extreme northwestern and southeastern raions located within the mountain range of the Ukrainian Carpathians. The mountainous terrain here is combined with the peripheral of their areas and low socio-economic development.

The low level of socio-economic development characterizes the vast majority of territorial units with low CNII.

A particular attention should be paid to the "peaks" around the regional centers and adjacent areas in the "communication landscape" of Western Ukraine (Fig. 2). The "uplift" in the Lviv area is especially noticeable. The cities of regional subordination form slightly smaller "hills". These cities are powerful socio-economic and transport centers: Volodymyr, Kovel, Dubno, Chortkiv, Mukachevo, as well as the cities of Precarpathia (Sambir, Drohobych, Stryi, Kolomyia). The major territory of Lvivska oblast, the Precarpathian region, the plain part of Zakarpattia, and the central parts of Volynska and Rivnenska oblasts are located on a "plateau".

The depressions of the "communication landscape" of Western Ukraine are the Ukrainian Carpathians, the eastern and western parts of the Ternopilska oblast (agrarian raions), the extreme northern part of the Ukrainian Polissia. In addition, "communication depressions" can be observed between powerful communication centers. These areas have found themselves away from the main transport highways, so called "periphery in the center". For example, Lokachynskyi raion is located between the cities of Lutsk, Kovel and Volodymyr; Demydivskyi raion is situated between Lutsk, Rivne, international highways Kyiv-Chop and Brest-Chernivtsi; Peremyshlianskyi and Berezhanskyi raions are located between Lviv, Ternopil, and Ivano-Frankivsk cities (Fig. 2). This can be explained by the polarization trends in the socio-economic development of any area. In other words, not all areas can be equally developed. When a center arises or forms, the periphery immediately emerges. The powerful centers (in our case, communication centers) seem to "extract" resources from the surrounding areas, forming "hollows" (socio-economic peripheries).

In Western Ukraine, the entire area along the state border lacks a high level of communication networks development. The increased CNII is typical only for the Ukrainian-Polish border (raions of Volynska and Lvivska oblasts where powerful checkpoints are located), and the west of Zakarpatska oblast, where the borders of the three states, namely Ukraine, Slovakia, and Hungary, converge (Fig. 2). Therefore, the

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state border of Ukraine continues mostly to perform a barrier function rather than a contact one.

The communication networks integrated index in the raions and cities of Western Ukraine ranges from 0.536 (Perechyn raion) to 2.469 (Lviv City). The average value is 1.098.

Analyzing the relationship between the level of socio-economic development and communication networks

We used the *territory development index* (6) to analyze the overall level of the development areas of Western Ukraine. Therefore, according to the TDI, oblast centers are distinguished among the territorial units of Western Ukraine (Fig. 3). Predicatbly, Lviv City stands out in terms of development (TDI = 12.773). Lutsk City ranks second (TDI = 8.894). All oblast centers have TDI > 0.700. The cities of regional subordination completely utterly dominate at the top of the ranking. Among the raions, Yavorivskyi raion of Lvivska oblasts has the highest TDI (TDI = 4.838, rank 27th). Uzhhorodskyi, Tiachivskyi, Lutskyi, Pustomytivskyi, Rakhivskyi, Rivnenskyi, Zhovkivskyi, Kostopilskyi, Ternopilskyi, Sarnenskyi, Dolynskyi, Vynohradivskyi, Bereznivskyi, Zolochivskyi, Verkhovynskyi raions also have a high TDI (0.400--4.593). The vast majority of raions have TDI within 0.300-0.400. Mlynivskyi, Sambirskyi, Ivanychivskyi, Kaluskyi, Hertsaivskyi, and Demydivskyi districts show the lowest level of development (< 0.250) (Fig. 3).

To determine the relationship between the level of the communications development and the level of the area development, 741 Pearson's pair correlation coefficients were calculated among 39 indicators of the communication networks development level (including TNI, CNI, SNI, MNI, CNII) and 19 indicators of the area development level (18 indicators and TDI). The results are presented in the correlation matrix form (Table 1).

The statistical significance level ($p < 0.05\%$) is for 533 indicators of the correlation matrix (comprising 71.3% of the values). It indicates that the obtained results can be trusted with high reliability. According to the tightness of the relationship, the following distribution is observed: a very strong relationship (the correlation coefficient r is > 0.9 and < -0.9) has 30 (4.05%) values, a strong relationship (r = -0.89 – -0.7; r = 0.7-0.89) has 49 (6.61%) values, a moderate relationship (r = -0.69 – -0.5; r = 0.5-0.69) has 121 (16.33%) values, a weak relationship (r = -0.49 – -0.2; r = 0.2-0.49) has 301 (40.62%) values, a very weak relationship (-0.19 < r < 0.19) has 240 (32.39%) values. Therefore, due to the lack of clear, unambiguous indicators of regional development, the relationship between most indicators is weak or very weak. The moderate and strong relationship (r > 0.5; r < -0.5) is observed only between 200 indicators (27.0%). It indicates that the regional development is a complex concept that cannot be reduced to a well-defined list of criteria. However, the correlation coefficient between the two main indicators, particularly CNII and TDI, is high (r = 0.79) and generally indicates a strong relationship between the level of communications development and the area development.

The moderate and strong relationship (r > 0.5; r < -0.5) between the *territorial development index* (TDI) and the indicators of communication networks is observed in 46.15% cases (very weak is only in 5.13%). The TDI has a particularly close relationship (r > 0.7; r < -0.7) with the density of the highways (r = 0.70), a number of arrivals (r = 0.72), a number of departures (r = -0.72), the volume of migrations (r = 0.73) and all indicators of the social network services distribution (r = 0.73-0.84). Among all indicators, the TDI has the highest correlation coefficient with the SNI (r = 0.84), which confirms our second hypothesis that the penetration level of the social network service can be an indicator of the socio-economic area development.

The indicators of the *transport component* of communication networks correlate with the indicators of the area development level on the average scale. The correlation coefficients of more than 0.5 and less than -0.5 (moderate and strong relationship) are observed only in 22.97%. It indicates the high transport development of Western Ukraine and the lack of deep contrasts in communication routes.

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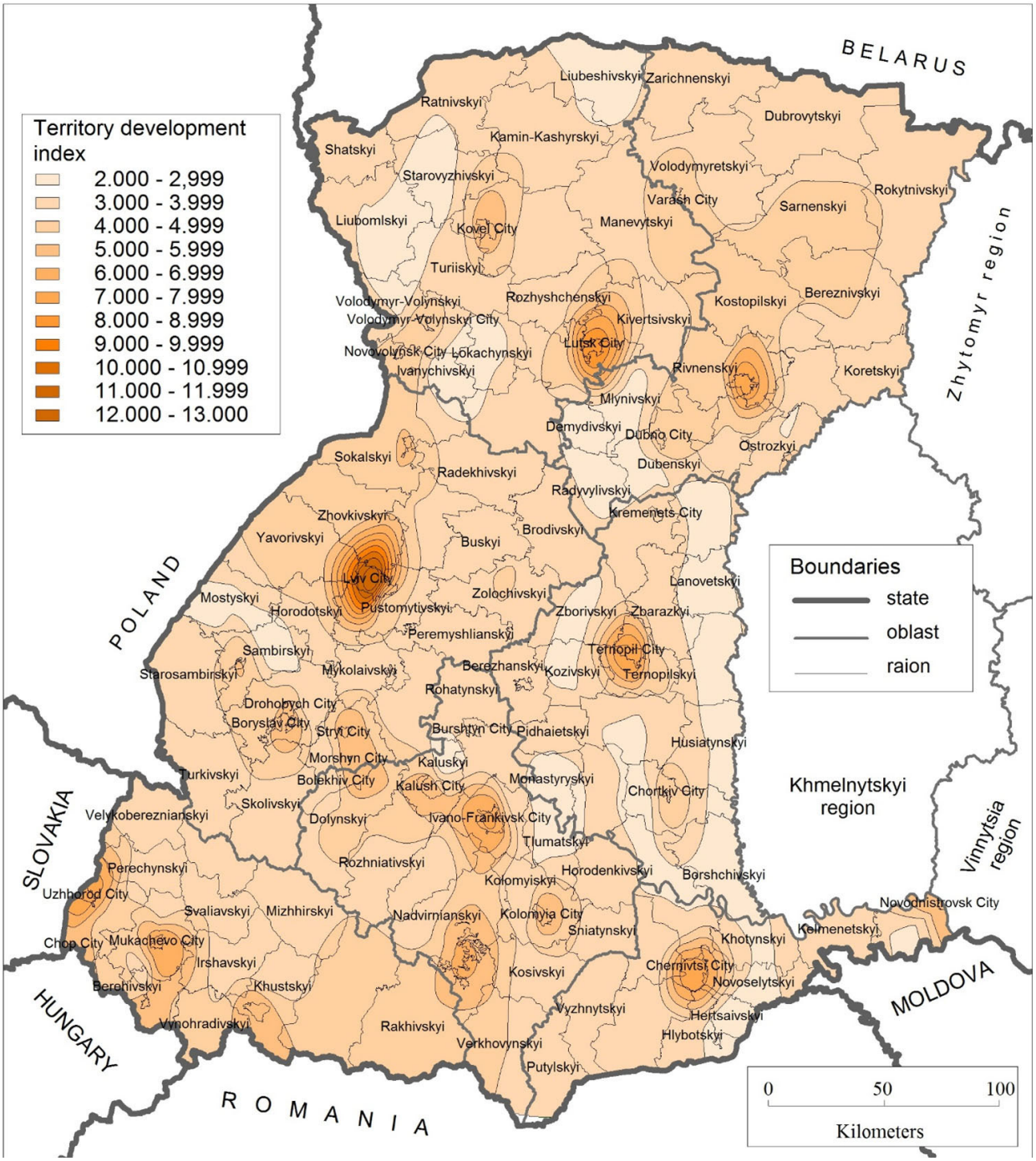

Fig. 3. Territory development index in Western Ukraine
Source: own preparation based on data from State statistics services of Ukraine.

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Table 1. Correlation matrix between area development indicators and communication networks in Western Ukraine

	x1*	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	TDI
t1	**0.24****	**0.58**	0.01	-0.10	**0.51**	**0.24**	**0.47**	0.02	**0.51**	0.08	**0.53**	**0.21**	**0.56**	0.03	**0.56**	0.05	**-0.51**	**-0.23**	**0.30**
t2	**-0.37**	0.11	**0.57**	**0.47**	0.16	**0.28**	0.16	0.05	**0.17**	**0.33**	**0.17**	**0.40**	0.15	**0.26**	0.15	**0.27**	-0.13	**-0.20**	**0.38**
t3	**-0.32**	0.06	**0.46**	**0.39**	0.11	**0.26**	0.10	0.02	0.11	**0.30**	0.11	**0.38**	0.09	**0.24**	0.09	**0.26**	-0.08	**-0.18**	**0.32**
t4	**0.80**	0.08	**-0.62**	**-0.71**	-0.08	**-0.36**	-0.10	**-0.20**	-0.07	**-0.46**	-0.06	**-0.36**	-0.01	**-0.38**	-0.01	**-0.38**	0.00	-0.03	**-0.40**
t5	**-0.72**	**0.32**	**0.91**	**0.82**	**0.40**	**0.62**	**0.42**	**0.24**	**0.43**	**0.72**	**0.39**	**0.61**	**0.34**	**0.29**	**0.34**	**0.30**	**-0.21**	-0.15	**0.70**
t6	**0.30**	**-0.26**	**-0.52**	**-0.60**	**-0.24**	**-0.31**	**-0.21**	**-0.17**	**-0.27**	**-0.37**	**-0.25**	**-0.39**	**-0.28**	**-0.45**	**-0.28**	**-0.46**	0.13	0.12	**-0.53**
t7	-0.02	**0.71**	**0.35**	**0.19**	**0.69**	**0.50**	**0.68**	**0.18**	**0.69**	**0.32**	**0.69**	**0.44**	**0.66**	0.04	**0.66**	0.06	**-0.52**	**-0.25**	**0.55**
t8	0.06	0.06	0.00	0.01	0.07	**0.17**	0.11	**0.35**	0.06	0.06	0.06	0.12	0.03	-0.15	0.03	-0.15	-0.02	-0.11	0.07
t9	**-0.18**	**0.66**	**0.42**	**0.23**	**0.62**	**0.53**	**0.57**	0.15	**0.66**	**0.45**	**0.64**	**0.55**	**0.61**	0.15	**0.61**	0.16	**-0.39**	**-0.18**	**0.59**
t10	**-0.17**	**0.22**	**0.22**	0.13	**0.18**	**0.37**	**0.17**	0.14	**0.23**	**0.37**	**0.21**	**0.46**	**0.19**	0.11	**0.18**	0.12	-0.04	-0.10	**0.31**
TNI	0.01	**0.58**	**0.31**	0.08	**0.54**	**0.46**	**0.53**	0.15	**0.56**	**0.34**	**0.55**	**0.46**	**0.52**	-0.05	**0.52**	-0.03	**-0.40**	**-0.27**	**0.45**
c1	**0.67**	0.15	**-0.51**	**-0.58**	-0.05	**-0.32**	-0.07	-0.17	-0.02	**-0.39**	-0.02	**-0.25**	0.06	**-0.25**	0.06	**-0.25**	0.00	-0.03	**-0.29**
c2	**-0.76**	**0.24**	**0.85**	**0.87**	**0.32**	**0.59**	**0.31**	**0.29**	**0.35**	**0.71**	**0.32**	**0.61**	**0.26**	**0.31**	**0.26**	**0.32**	-0.17	-0.15	**0.67**
c3	**0.85**	-0.06	**-0.58**	**-0.62**	**-0.18**	**-0.40**	**-0.17**	**-0.19**	**-0.19**	**-0.56**	**-0.17**	**-0.41**	-0.12	**-0.35**	-0.12	**-0.35**	0.08	-0.01	**-0.43**
c4	**-0.42**	0.12	**0.43**	**0.41**	**0.20**	**0.41**	**0.18**	-0.02	**0.19**	**0.31**	**0.18**	**0.33**	0.11	-0.10	0.11	-0.09	-0.12	**-0.17**	**0.27**
c5	**0.67**	0.02	**-0.55**	**-0.60**	-0.12	**-0.27**	-0.12	-0.14	-0.12	**-0.44**	-0.11	**-0.29**	-0.04	**-0.26**	-0.04	**-0.26**	0.05	-0.05	**-0.35**
c6	**-0.67**	**0.20**	**0.62**	**0.66**	**0.27**	**0.59**	**0.27**	**0.25**	**0.28**	**0.58**	**0.26**	**0.56**	**0.22**	**0.24**	**0.21**	**0.25**	-0.14	-0.15	**0.54**
c7	**0.49**	0.02	**-0.38**	**-0.39**	-0.06	-0.16	-0.06	-0.08	-0.08	**-0.33**	-0.06	**-0.22**	-0.01	-0.15	-0.01	-0.14	0.00	-0.10	**-0.22**
c8	**-0.61**	0.16	**0.70**	**0.74**	**0.26**	**0.53**	**0.27**	**0.28**	**0.26**	**0.57**	**0.24**	**0.49**	**0.20**	**0.30**	**0.20**	**0.31**	-0.15	-0.14	**0.56**
c9	**0.65**	0.03	**-0.45**	**-0.52**	-0.08	**-0.24**	-0.08	-0.11	-0.09	**-0.37**	-0.07	**-0.20**	-0.02	**-0.20**	-0.02	**-0.20**	0.02	-0.03	**-0.26**
c10	**-0.68**	**0.21**	**0.73**	**0.76**	**0.31**	**0.59**	**0.30**	**0.26**	**0.32**	**0.65**	**0.30**	**0.61**	**0.24**	**0.26**	**0.24**	**0.27**	-0.16	**-0.17**	**0.61**
c11	**0.63**	0.03	**-0.53**	**-0.62**	-0.11	**-0.28**	-0.12	-0.16	-0.10	**-0.37**	-0.09	**-0.26**	-0.05	**-0.31**	-0.05	**-0.31**	0.04	-0.06	**-0.35**
c12	**-0.70**	**0.20**	**0.68**	**0.67**	**0.27**	**0.57**	**0.25**	**0.26**	**0.29**	**0.67**	**0.26**	**0.58**	**0.21**	**0.24**	**0.20**	**0.25**	-0.13	**-0.17**	**0.55**
CNI	**-0.17**	**0.26**	**0.36**	**0.33**	**0.24**	**0.41**	**0.23**	0.15	**0.25**	**0.34**	**0.24**	**0.40**	**0.23**	0.03	**0.22**	0.05	-0.15	**-0.23**	**0.36**
s1	**-0.25**	**0.94**	**0.57**	**0.40**	**0.97**	**0.58**	**0.90**	0.16	**0.98**	**0.47**	**0.97**	**0.52**	**0.96**	**0.24**	**0.96**	**0.26**	**-0.82**	**-0.28**	**0.79**
s2	**-0.60**	**0.34**	**0.75**	**0.82**	**0.41**	**0.57**	**0.39**	**0.29**	**0.45**	**0.69**	**0.41**	**0.57**	**0.38**	**0.42**	**0.37**	**0.43**	**-0.21**	-0.08	**0.73**
s3	**-0.24**	**0.95**	**0.56**	**0.39**	**0.96**	**0.57**	**0.89**	0.16	**0.98**	**0.47**	**0.97**	**0.52**	**0.95**	**0.23**	**0.95**	**0.25**	**-0.80**	**-0.27**	**0.79**
s4	**-0.54**	**0.39**	**0.73**	**0.80**	**0.44**	**0.56**	**0.42**	**0.32**	**0.50**	**0.70**	**0.46**	**0.59**	**0.42**	**0.40**	**0.41**	**0.41**	**-0.21**	-0.06	**0.75**
SNI	**-0.52**	**0.60**	**0.77**	**0.76**	**0.66**	**0.63**	**0.62**	**0.29**	**0.70**	**0.70**	**0.67**	**0.63**	**0.64**	**0.40**	**0.63**	**0.41**	**-0.44**	-0.15	**0.84**
m1	**-0.17**	**0.91**	**0.50**	**0.31**	**0.94**	**0.62**	**0.85**	0.15	**0.92**	**0.40**	**0.92**	**0.51**	**0.88**	0.14	**0.88**	0.16	**-0.77**	**-0.34**	**0.72**
m2	0.15	**-0.93**	**-0.52**	**-0.32**	**-0.95**	**-0.56**	**-0.87**	-0.14	**-0.93**	**-0.36**	**-0.93**	**-0.46**	**-0.92**	-0.15	**-0.92**	**-0.18**	**0.78**	**0.31**	**-0.72**
m3	-0.15	**0.41**	**0.20**	0.13	**0.47**	**0.49**	**0.39**	0.13	**0.44**	**0.33**	**0.45**	**0.43**	**0.35**	0.03	**0.35**	0.05	**-0.37**	**-0.25**	**0.37**
m4	-0.16	**0.93**	**0.51**	**0.32**	**0.95**	**0.60**	**0.87**	0.15	**0.93**	**0.39**	**0.93**	**0.49**	**0.91**	0.15	**0.91**	**0.17**	**-0.79**	**-0.33**	**0.73**
m5	**-0.24**	0.14	**0.34**	**0.34**	**0.25**	**0.42**	**0.22**	0.14	**0.20**	**0.22**	**0.21**	**0.34**	0.12	-0.03	0.12	-0.02	-0.14	**-0.23**	**0.28**
m6	**0.27**	0.05	**-0.33**	**-0.41**	-0.09	**-0.21**	-0.09	-0.15	-0.02	-0.01	-0.03	-0.04	0.02	0.05	0.01	0.04	0.05	**0.18**	-0.13
m7	-0.02	**0.28**	0.08	-0.01	**0.27**	**0.38**	**0.22**	0.02	**0.28**	**0.33**	**0.28**	**0.47**	**0.21**	0.02	**0.21**	0.03	-0.15	-0.12	**0.27**
m8	**-0.27**	0.06	**0.35**	**0.39**	**0.18**	**0.34**	**0.17**	0.15	0.12	0.13	0.14	**0.22**	0.06	-0.04	0.06	-0.03	-0.11	**-0.22**	**0.23**
MNI	-0.17	**0.46**	**0.31**	**0.22**	**0.51**	**0.56**	**0.45**	0.12	**0.49**	**0.38**	**0.49**	**0.53**	**0.41**	0.03	**0.41**	0.05	**-0.37**	**-0.26**	**0.46**
CNII	**-0.38**	**0.65**	**0.69**	**0.60**	**0.68**	**0.73**	**0.63**	**0.27**	**0.70**	**0.66**	**0.68**	**0.71**	**0.63**	**0.21**	**0.63**	**0.23**	**-0.46**	-0.29	0.79

* See chapter "MATERIALS AND METHODS"

** Correlation coefficients for which $p < 0.05$ are highlighted in bold

Source: own preparation based on Geofabrik (2021); MobUA.net (2021); State Statistics Service of Ukraine (2021).

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Even in the Ukrainian Carpathians, where the cost of construction and infrastructure operation is much higher than in the flat area, the roads are of fairly high quality. We noted a strong relationship ($r > 0.7$; $r < -0.7$) between the length of roads and the area of the territory ($r = 0.80$), the urbanization level ($r = -0.71$), the density of roads and the area of the territory ($r = -0.72$), the population density ($r = 0.91$), the urbanization level ($r = 0.82$), the number of individual entrepreneurs per 1000 people ($r = 0.72$), the TDI ($r = 0.70$), and the volume of goods transported by automobile transport and the population ($r = 0.71$). Therefore, among the road network in Western Ukraine, the leading role is with the automobile ones. They also form the socio-economic profile of the area. Today, railways are facing the period of stagnation, so their importance in socio-economic development is much lower compared to the roads.

The component of the *mobile connection* among all blocks of communication networks correlates at its weakest with the area development indicators. The moderate and strong correlation ($r > 0.5$; $r < -0.5$) is observed only in 19.83% of cases. It indicates that mobile connection has transitioned from an innovation to a daily practice in Western Ukraine nowadays. A stable 2G/3G mobile signal of at least one of the mobile operators (most often Kyivstar) is present with almost all settlements and the majority of main highways. It is noticeable that the cellular networks development level is very weakly dependent on the budget deficit/surplus ($-0.19 < r < 0.19$) and on the total population ($r = -0.06$-0.26). This once again proves that mobile connection is widespread everywhere today.

The social network services are most closely related to the indicators of the area development. The correlation coefficients of more than 0.5 and less than -0.5 (a moderate and a strong relationship) are observed in 55.79% cases. It indicates the innovative nature of social network services and the possibility of using them as one of the indicators of socio-economic development. This confirms the second hypothesis of our study. The high coefficients of paired correlation are typical mainly for the absolute indicators. The Facebook and Instagram indicators form largely similar patterns. This is evidence that different social networks have a common internal nature and similar features in spatial development.

The *migration component* of communication networks has medium levels of relationship with the socio-economic situation in the region. Only 21.64% of paired correlation indicators have moderate and strong relationship ($r > 0.5$; $r < -0.5$). This indicates, first of all, the imperfection of accounting for migration processes in Ukraine since, as is well known, population migration is one of the indicators of the area's attractiveness. The high coefficients of paired correlation are typical mainly for the absolute indicators. Due to the imperfection of the state registration of migration movements, one of the main migration indicators, specifically the balance of population migration, demonstrates low correlation coefficients.

Between the *communication networks integrated index* (CNII) and indicators of socio-economic development of the area, a moderate and strong relationship ($r > 0.5$; $r < -0.5$) is observed already in 68.42% (a weak relationship is in 31.58%, and a very weak one is absent). This can serve as evidence that the area's socio-economic development has a more significant impact on the functioning of communication networks than communication networks have on socio-economic development (see the data/information/paragraph above, TDI). A strong relationship ($r > 0.7$; $r < -0.7$) is traced between the CNII and the number of legal entities per 1000 people ($r = 0.73$), the number of individual entrepreneurs ($r = 0.70$), the volume of sales of individual entrepreneurs per 1 person ($r = 0.71$), and the TDI ($r = 0.79$).

Therefore, the communication networks integrated index (CNII) has one of the highest (the higher values are only with the CNI) coefficients of paired correlation with the indicators of socio-economic development. The CNII can be a kind of an indicator for the socio-economic development of the area.

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LIMITATIONS

The current economic and political situation in Ukraine imposes limitations on the findings of this study. The choice to focus on the 2016–2020 time period for the study was made for various reasons.

Consequently, the number of raions decreased from 490 to 136, with a significant increase in their size. These new raions are vast, which makes it impossible to thoroughly analyze the spatial features of the communication networks. Collecting statistical indicators for the new lowest administrative-territorial units (hromadas) is not yet possible.

Additionally, following the beginning of the war on February 24, 2022, some statistical indicators and cartographic web services in Ukraine became no longer accessible.

Furthermore, the official demographic data (especially migration figures) have low accuracy. Ukraine conducted its last population census in 2001.

That is, our analysis reflects the pre-reform and the pre-war condition of communication networks in Western Ukraine.

CONCLUSIONS AND DISCUSSION

To summarize, the communication networks of the territory are geographical complexes formed by a large number of various economic, social, and natural objects, for the functioning of each one, the spatial component is important. The main communication networks are transport, cellular, social, and migration networks.

When analyzing the individual components of the "communication landscape", the similar patterns are observed. This confirms the common nature of communications of various types, including even seemingly incompatible ones (for example, transport networks and social network services). The CNII indicates the general state of functioning and development of communication networks in the area, the communication level between individuals, and the general condition of the population mobility. The regional centers and adjacent areas have the highest rates of CNII. Lvivska oblast, the Precarpathians, the plain part of Transcarpathia, the central parts of Volynska and Rivnenska oblasts have a high level of the communication networks development. The low CNII values are typical for the Ukrainian Carpathians, the eastern and western parts of the Ternopilska oblast, the extreme northern part of the Volyn Polissia. In addition, the minimum CNII values can be observed amongst powerful communication centers. This confirms the *third hypothesis* of our study.

The communication networks are closely interconnected and interact with the socio-economic area development. It is not always possible to say unequivocally what cause and effect are in a particular case. As a rule, the construction of new communications leads to the activation of the socio-economic development of the areas. At the same time, more developed areas have a greater need for communications, which encourages their development. On the other hand, there is evidence that the construction of new powerful communications that only sometimes lead to economic growth (for example, the Baikal--Amur Mainline in the USSR). It can be traced at the micro level at the empirical dependence dated back to the 1970s. The laying of the asphalt road to a rural settlement leads to an increase in the migration outflow of the population from it (Homra, 1979).

The correlation analysis shows significant links between communications and the development of areas. Although most coefficients of paired correlation have a moderate relationship, the correlation coefficients between the two main indicators (the CNII and the TDI) are high ($r = 0.79$). It generally indicates a strong relationship between the level of communications development and the level of the area development.

According to the results of our study, the socio-economic development in Western Ukraine has a more significant impact on the functioning of communication networks than communication networks have on socio-economic development. This confirms the *first hypothesis* of our study.

The social network services are most closely related to the indicators of the area development. It confirms the *second hypothesis* of our study and indicates the innovative nature of the SNSs and the

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possibility of using them as one of the indicators of socio-economic development.

Like other natural and socio-economic resources, the communication networks are only prerequisites for the area's development. The emergence, the perception by the population, and the widespread of new communications depend on some factors, among which an important place belongs to the socio-economic development level of the area.

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REFERENCES

AdEspresso. (2023). *The Beginner's Guide to Facebook Audiences and Targeting*. https://adespresso.com/guides/facebook-ads-beginner/demographic-targeting

Bailey, M., Cao, R., Kuchler, T., Stroebel, J., & Wong, A. (2018). Social Connectedness: Measurement, Determinants, and Effects. *Journal of Economic Perspectives, 32*(3), 259–280. https://doi.org/10.1257/jep.32.3.259

Eagle, N., Macy, M., & Claxton, R. (2010). Network diversity and economic development. *Science, 328*(5981), 1029–1031. https://doi.org/10.1126/science.1186605

Facebook. (2023). *Meta for Business. Marketing on Facebook*. https://www.facebook.com/business

Fedyuk, O., & Kindler, M. (Eds.). (2016). *Ukrainian migration to the European Union: lessons from migration studies*. Springer Nature. https://doi.org/10.1007/978-3-319-41776-9_14

Geofabrik. (2021). *Download OpenStreetMap data for this region: Ukraine (with Crimea)*. https://download.geofabrik.de/europe/ukraine.html

Griškevičiūtė-Gečienė, A., & Griškevičienė, D. (2016). The Influence of Transport Infrastructure Development on Sustainable Living Environment in Lithuania. *Procedia Engineering, 134*, 215–223. https://doi.org/10.1016/j.proeng.2016.01.062

GSMA. (2023a). *About the GSM Association*. https://www.gsma.com/

GSMA. (2023b). *Mobile for Development*. https://www.gsma.com/mobilefordevelopment

Homra, A. U. (1979). *Population migration: issues of theory, research methods*. Naukova Dumka. [In Russian].

Hrytsevych, V. S., & Senchuk, H. V. (2008). Historical and geographical features of the railway network development in the Western region of Ukraine. *Scientific Notes Ternopil National Volodymyr Hnatyuk Pedagogical University. Series: Geography, 2*, 9–12. [In Ukrainian].

Hrytsevych, V. S., & Senchuk, H. V. (2010). Road transport network of the Carpathian region of Ukraine in the context of European integration. *Scientific Notes of Ternopil National Volodymyr Hnatyuk Pedagogical University. Series: Geography, 2*, 52–58. [In Ukrainian].

Hrytsevych, V. S., & Senchuk, H. V. (2011a). Polyhighways of the Carpathian region of Ukraine. *Scientific Notes Ternopil National Volodymyr Hnatyuk Pedagogical University. Series: Geography, 2*, 78–83. [In Ukrainian].

Hrytsevych, V. S., & Senchuk, H. V. (2011b). The curvature of the motor vehicle space of the Carpathian region of Ukraine. *Human geography journal, 10*, 122–127. [In Ukrainian].

Jóźwiak, I., & Piechowska, M. (2017). Crisis-driven mobility between Ukraine and Poland: What does the available data (not) tell us. *CMR Working Papers, 99*(157), 1–26.

Khanna, P. (2016). *Connectography: Mapping the Future of Global Civilization*. Random House.

Komornicki, T., & Szejgiec-Kolenda, B. (2023). The development of transport infrastructure in Poland and the role of spatial planning and cohesion policy in investment processes. *Planning Practice & Research, 38*(5), 694–713. https://doi.org/10.1080/02697459.2020.1852677

Kowalski, M., & Wiśniewski, S. (2019). Transport accessibility and mobility: a forecast of changes in the face of planned development of the network of expressways and motorways in Poland. *European Spatial Research and Policy, 26*(2), 151–176. https://doi.org/10.18778/1231-1952.26.2.08

Kyivstar. (2023). *Big Data Kyivstar: the number of internal tourists in Ukraine decreased by 17% in 2020*. [In Ukrainian]. https://kyivstar.ua/uk/mm/news-and-promotions/big-data-kyyivstar-kilkist-vnutrishnih-turystiv-v-ukrayini-u-2020-roci

Malynovska, O. A. (2018). *Migration policy: global context and Ukrainian realities*. NISD. [In Ukrainian].

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Marin, G., & Olaru, M. (2015). Modal strategic decisions in transport and their role in sustainable development: An example from Romania. *Procedia Economics and Finance, 32*, 657–664. https://doi.org/10.1016/S2212-5671(15)01446-X

Masárová, J., & Ivanová, E. (2016). Road infrastructure in the regions of the Slovak Republic and Poland. *Bulletin of Geography. Socio-Economic Series, 33*, 79–90. https://doi.org/10.1515/bog-2016-0026

Mensah, J. T. (2021). Mobile phones and local economic development: a global evidence. *Social Science Research Network*. http://dx.doi.org/10.2139/ssrn.3811765

MobUA.net. (2021). *Consolidated coverage map of all 3G/4G operators in Ukraine*. https://www.mobua.net/maps

Munshi, K. (2016). Community Networks and Migration. In Y. Bramoullé, A. Galeotti, & B. W. Rogers (Eds.), *The Oxford Handbook of the Economics of Networks* (pp. 630–648). Oxford Handbooks. https://doi.org/10.1093/oxfordhb/9780199948277.013.29

O'Dell, A., & Richards, P. (1971). *Railways and Geography*. Hutchinson & Co.

Ogryzek, M., & Wolny-Kucińska, A. (2021). Sustainable Development of Transport as a Regional Policy Target for Sustainable Development – A Case Study of Poland. *ISPRS International Journal of Geo-Information, 10*(3), 132. https://doi.org/10.3390/ijgi10030132

Pikulyk, O. B. (2009). *Transport infrastructural support for the socio-economic development of the Western region of Ukraine* [Unpublished PhD dissertations]. Dolishniy Institute of Regional Research. [In Ukrainian].

Plusone social impact. (2023). *Facebook and Instagram in Ukraine (January 2023)*. https://plusone.com.ua/research/en/

Pozniak, O. V. (Ed.). (2007). *Migration processes in Ukraine: contemporary state and perspectives*. SPD Sochinsky. [In Ukrainian].

Puhach, S. (2021). *Social geography of communication networks in Western Ukraine*. Teren. [In Ukrainian].

Puhach, S., & Mezentsev, K. (2021). The unevenly absorbed and induced intra-regional Facebook adoption in Western Ukraine. *Acta Universitatis Carolinae Geographica, 56*(2), 157–167. https://doi.org/10.14712/23361980.2021.10

Puhach, S., Mezentsev, K., & Gnatiuk, O. (2021). Social networking in the everyday life of student youth in Western Ukraine. *Geografický časopis, 73*(3), 283–295. https://doi.org/10.31577/geogrcas.2021.73.3.15

Puhach, S., Lazhnik, V., & Kandyba, Yu. (2022). Regional development of Kyivstar mobile communication network in Western Ukraine. *Ekonomichna ta Sotsialna Geografiya*, *88*, 16–22. [In Ukrainian]. https://doi.org/10.17721/2413-7154/2022.88.16-22

Ray, C., & Talbot, H. (1999). Rural telematics: The Information Society and rural development. In M. Crang, P. Crang, & J. May (Eds.), *Virtual Geographies. Bodies, space and relations* (pp. 149–163). Routledge.

Rodrigue, J.-P. (2020). *The Geography of Transport Systems* (5th ed.). Routledge.

Rokicki, B., & Stępniak, M. (2018). Major transport infrastructure investment and regional economic development – An accessibility-based approach. *Journal of Transport Geography, 72*, 36–49. https://doi.org/10.1016/j.jtrangeo.2018.08.010

Rovenchak, O. A., & Volodko, V. V. (2015). *International migration: theory and practice*. Ivan Franko National University of Lviv. [In Ukrainian].

Sadova, U. Ya. (Ed.). (2019). *Migration in the context of regional labor markets transformation in Ukraine: regulatory mechanisms*. Dolishniy Institute of Regional Research. [In Ukrainian]. http://ird.gov.ua/irdp/p20190006.pdf

Schmidt, E., & Cohen, J. (2013). *The new digital age: reshaping the future of people, nations, and business*. Alfred A. Knopf.

Senkiv, M. I. (2016). Cartographic and geologistic characteristics of the Western region of Ukraine. *Magazine of cartography, 14*, 302–315. [In Ukrainian].

Senkiv, M. I. (2017). *Transport and distribution geologistics in the Western region of Ukraine* [Unpublished PhD dissertations]. Ivan Franko National University of Lviv. [In Ukrainian].

State Statistics Service of Ukraine. (2021). *Statistical Information*. http://www.ukrstat.gov.ua

Strelko, O., Solovyova, O., Berdnychenko, Y., Kyrychenko, H., & Solovyova, L. (2023). Study of the contemporary trends in the development of transport systems of the Ukrainian railways. *Acta Scientiarum Polonorum. Administratio Locorum*, *22*(2), 263–279. https://doi.org/10.31648/aspal.8444

Talbot, H. (1997). *Telematics for the Rural North*. Northern Informatics.

Tóth, G. (2009). Analysis of public road accessibility in Hungary. In *Current trends in statistics in V6 region* (pp. 108–117). Czech Statistical Office. http://real.mtak.hu/17252/1/selection%20%2815%29.pdf

Urry, J. (2007). *Mobilities*. Polity Press.

Zapadniuk, S. O. (2011). *Migration of Ukrainian population: preconditions, dynamics and development*. NAS of Ukraine. [In Ukrainian].

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