Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ.Geol.Geograph. Geology, 30(2), 389–401.
doi: 10.15421/112135

Geoinformation technologies as a basis for research of the optimal location of general secondary education institutions (on the example of Chernivtsi city territorial community)

Myroslav D. Zayachuk, Ivan I. Kostashchuk, Kostiantyn V. Darchuk, Yurii O. Bilous

Yuriy Fedkovych Chernivtsi National University, Chernivtsi, Ukraine,
m.zayachuk@chnu.edu.ua, i.kostaschuk@chnu.edu.ua, m.zayachuk@chnu.edu.ua, y.bilous@chnu.edu.ua

Received: 03.03.2021
Received in revised form: 26.03.2021
Accepted: 30.03.2021

Abstract. GIS technologies allow an analyzis of large data sets at the lowest cost. To date, when forming a network of secondary schools, almost no geographic information systems have been used. GIS plays a special role in the study of transport and walking accessibility to GSEI. The article analyzes the theoretical, methodological and practical problems of using geographic information systems in studies of walking accessibility to general secondary schools of Chernivtsi city territorial community and describes the general secondary education institutions of the studied community. Based on geoinformation systems developed in Open Route Service and QGIS, the areas of the community with the best and worst walking accessibility to secondary schools were identified, which is certainly of great practical importance in creating pivotal institutions, their service zone and overcoming the problem of overcrowding in some schools. The most convenient location of the general secondary education institutions of Chernivtsi city territorial community was observed in the central part of the city, as well as in microdistricts Prospect and Boulevard, where there is a fairly dense arrangement of general secondary education institutions. There are also areas in the community that are outside the 2-kilometer walking accessibility zone and require transportation for students. Such areas are the Shantsi, Tsetsyno and Slobidka and Rohizna microdistricts, which have a cottage type accommodations. In general, most of the community is within walking accessibility. An important aspect of the location of GSEI is the availability indicator, which ranges 0.2 to 0.81. The average rate of accessibility to GSEI in the Chernivtsi city territorial community is 0.65. It should be noted that in the community there is a relevant problem of providing students with places in GSEI in those areas, where today the construction of new residential areas is actively carried out, while educational institutions are not expanding and not being built.

Keywords: geographic information systems, Open Route Service, QGIS, ArcGIS, walking accessibility, secondary education, general secondary education institution (GSEI)

Геоінформаційні технології як основа дослідження оптимального розташування закладів загальної середньої освіти (на прикладі Чернівецької міської територіальної громади)

М.Д. Заячук, І.І. Костащук, К.В. Дарчук, Ю.О. Білоус

Чернівецький національний університет ім. Ю. Федьковича, Чернівці, Україна,
m.zayachuk@chnu.edu.ua, i.kostaschuk@chnu.edu.ua, m.zayachuk@chnu.edu.ua, y.bilous@chnu.edu.ua

Анотація. В статті проаналізовано теоретичні, методичні та прикладні аспекти використання геоінформаційних систем з метою вивчення та аналізу оптимального розташування закладів загальної середньої освіти Чернівецької міської територіальної громади, визначення пішохідної доступності учнів до них; а також можливості їх застосування для проектування освітньої мережі. На основі побудованих цифрових картографічних моделей за допомогою веб-сервісу OpenRouteService та геоінформаційних систем ArcGIS та QGIS, визначено межі та структурні елементи територіальної громади, проаналізовано особливості функціонування загальноосвітньої мережі на території дослідження та виявлено зони з найкращою та найгіршою пішохідною доступністю до закладів загальної середньої освіти. Найкраще розташування закладів загальної середньої освіти Чернівецької міської територіальної громади спостерігається в центральній частині міста, а також у південних спальних мікрорайонах міста – Проспект та Бульвар, де відстежується досить щільне розміщення закладів загальної середньої освіти, що пояснюється в центральній частині історичними процесами формування міського простору, а в спальних районах – високою густотою населення та відповідно і чисельністю дітей шкільного віку. Встановлено, що в громаді наявні території, що знаходяться поза межами 2-х кілометрової зони пішохідної доступності та потребують організації підвезення учнів. Такими територіями є мікрорайони з котеджним типом забудови – Шанці, Цецино Слобідка та Рогізна, а також сільські населені пункти. Загалом більша частина території громади знаходиться в межах пішохідної доступності. Важливим аспектом розміщення

закладів загальної середньої освіти є показник доступності, який коливається від 0,2 до 0,81. Середній же показник доступності до закладів загальної середньої освіти в Чернівецькій міській територіальній громаді становить 0,65. Слід відмітити, що окраїнні рурални райони міста потребують підвезення учнів шкільними автобусами, що потребує вирішення міською владою. ГІС технології дозволяють проводити оцінку освітньої мережі, що дозволить запропонувати вирішення складних питань, які виникли в умовах реформування освіти.

Ключові слова: геоінформаційні системи,OpenRouteService, QGIS, ArcGIS, пішохідна доступність, середня освіта, заклад загальної середньої освіти

Introduction

High quality education is a precondition of the successful economic and social future of the state, and one of the most important factors of acquiring it is accessibility to students of the education institutions of various forms and types. In Ukraine, there are clearly outlined sanitary norms of locations and accessibility of institutions of general secondary education (IGSE), which should be taken into account when optimizing their network. Up to now, the geoinformational systems for studying transportation and walking distances have been almost unused during planning or optimizing the network of institutions of general education, which were then and now based rather on economic parameters. Research of walking accessibility to IGSE using the methods of spatial analysis is quite important and necessary, first of all in order to determine the territories with their various parameters, which has a practical significance for creation of pivotal schools [pivotal school refers to the main school of a community, education center in each administrative-territorial unit, where education is also provided to children of small surrounding settlements – *Translator`s note*] and strategic development of the general education network. Such an approach would allow our country to develop an optimum educational network, provide every student with access to high-quality education and multi-faceted development of his or her talents, based on principles and requirements of the New Ukrainian School. This in turn would increase the national security of the state (and particularly its economic and social constituents), and will contribute to sustainable development of the state, described in the Resolution of the General Assembly of the UN "Transforming our world: the 2030 Agenda for Sustainable Development", specifically goal 4 of this agenda, which is to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", and therefore the topic has both scientific-theoretic and practical significances.

Review of the literature, materials and methods of research

Research of optimum locations for institutions of general secondary education is a relatively new direction in socio-geographic science. Most scientific research has focused on the territorial differentiation of the educational network. Today, an important aspect is monitoring and justification of creating pivotal schools of the IGSE in spite of the ongoing de-centralizing processes in Ukraine. This issue has been studied the most by economists and geographers. Among economists, we should note the research of such scientists as Harchenko M., Pashkevych M., Bienovsky L., Palchuk V., Savchuk D. and others. Other research has focused on generalization and development of scientific-methodological development of the network of pivotal schools in the conditions of decentralization reform. Specifics of functioning national and regional educational complexes have been researched by geographers, particularly Oliinyk Y., Niemets L., Homra O., Statsky V., Melnychenko T., Kornus O., Nych T., Flint N., Zaiachuk O., Kostaschyk I., and many others. Among foreign researchers, we should note the works by Lakhotia S., Lassarre S., Rao K. R., Tiwari G., Colclough J. G., Owens E., Martínez-Jiménez E., Salinas-Pérez J. A. and others. Analysis of walking distance to the culture-educational network of Córdoba (Spain) using geodata technology is presented in the research by Enrique Martínez-Jiménez and Jose A. Salinas-Pérez. In their works, Shovan Ghosh, Sanat Kumar Guchhait and Susmita Sengupta reveal spatial peculiarities of development of infrastructure and level of development of secondary schools in India. Also, important researches were carried out by Colclough J. G.and Owens, E., which analyze the specifics of cartography of walking time using the methods of network models of GIS.

GIS-technologies are actively used in the development of urban planning, land use, development of hospital districts, etc. In general, use of geoinformational technologies is seen in different spheres of human activity. On the other hand, these technologies are poorly incorporated in research on educational networks, including locating educational institutions and planning the parameters of their optimum location.

The researches was conducted based on analysis of existing literature data in this topic, cartographic dimensions and use of GIS-technologies. We analyzed statistical materials related to the characteristics of the institutions of general secondary education in

Chernivtsi City Territorial Community, and using geoinformation systems, we developed zones of accessibility to educational institutions in the initial administrative-territorial unit. The best way of researching walking and riding distances is to use geoinformation systems, of which there currently are dozens of software products. Among them, we selected ArcGIS and QGIS to achieve the goals. Complex use of QGIS and ArcGIS solved the tasks of various complexity, particularly determining the coefficient of accessibility of the institutions, analysis of their spatial arrangement and identifying territories with varying degrees of accessibility, and the use of Open Route Service web service allowed us to solve those problems in interactive regime. At the moment, within the framework of Open Route Service, the following functions were implemented: directions, matrix of temporal distance; point of interest; Pelias geo-coding; elevation; isochrones (HeiGIT, 2020).

To study accessibility to IGSE by riding and walking, we propose using the method of structure of isochrones (zones of accessibility), which help determining from which points the students are able to walk to school in a certain time, as well as distance. When building isochrones, the following parameters are taken into account: steepness of slopes, types of roads, types of cover, complexity of roads and others. Accessibility zones can be made for cars and large vehicles (including buses, which is important when planning routes for driving children), travel distances by cycling and walking, and also moving in wheelchair. Polygons can be made according to distance or time, which is quite convenient and allows taking into account children's walking speed related to age. We think that research on local territorial communities with well developed transportation infrastructure and dense ISGE network on one hand, and uneven ISGE network on the other hand, should pay more attention to walking accessibility, rather than accessibility by cycling or riding. This will help planning not only the educational network, but help in the necessary process of organizing the transportation of children, and also help Chernivtsi Local Council in dividing the city into educational districts. On the other hand, in village communities, one should focus more on transportation infrastructure and optimization of financial expenditures for transportation of children to the pivotal schools.

The main material

Currently, Ukrainian society is at the stage of carrying out a de-centralization reform, which implies changes in the administrative-territorial structure of our country and imposes most duties (including provision and development of the education) of the state on the bodies of local government, which, together with receiving budget preferences and management obligations, should take on the complex task and responsibility of creating effective management of systems of education, medicine, culture and other spheres in their communities. An important aspect in this context is effective planning of arrangement of IGSE, optimization of their network, which manifests today in the creation of pivotal schools and their branches (Ridosh (Ed.), 2021).

After introduction of de-centralization reform, communities began to actively use data and geoinformational cartography software in the sphere of mana-

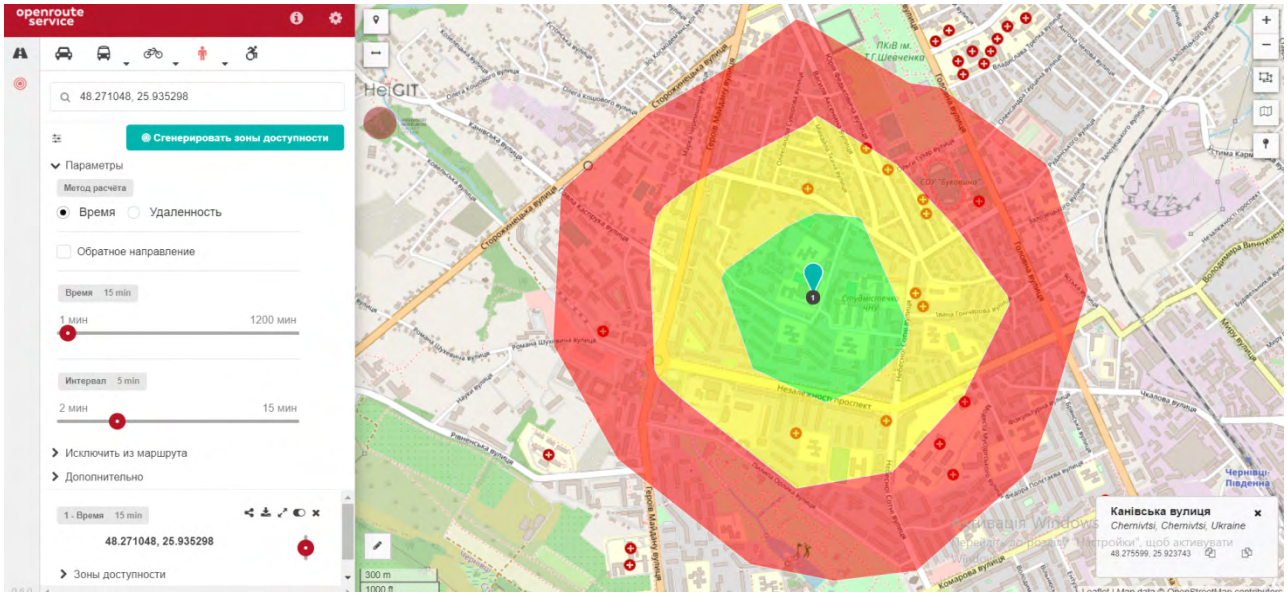

Fig. 1. Interface of Open Route Service web service for determining accessibility to the IGSE

gement of territories of inhabited areas. In most cases when they are being implemented, the "map and data base" approach is used ,which involves storing maps and attributive information in a data base. The main feature of GIS is using geospatial data base for presenting the data in the following forms: various documents based on developing maps; developing tables; texts using selections from the data base and geospatial modeling and analysis of the data obtained using the results of selection (Honcharov&Oliinyk, 2016).

Despite broad introduction of information technologies, geoinformation technologies are practically unused during planning of the educational network, and particularly creating pivotal institutions and optimizing the network of ISGE, especially at the local level. Therefore, it would be practical to consider these issues within separate territorial communities.

According to the new administrative-territorial structure, in Chernivtsi Oblast, 52 territorial communities have been created, including 34 village, 7 posyolok and 11 urban. For the research, we selected the Chernivtsi Local Territorial Community, which is the largest in Chernivtsi Oblast according to the population, number of students and number of the ISGE. The community includes three local settlements, namely Chernivtsi city and Chornivka and Koroviya villages. The area of the community is 181.6 km^2, and the population is 272,180 people (local population – 267,060 people and rural population – 5,120 people) (Ridosh (Ed.), 2020). Therefore, the average population density is 1,498.8 people/km^2.

During optimization of the general educational complex of the community, we took into account the number of factors: educational needs of students; organization of pre-profile training and profile (professional) education; qualification of pedagogic staff; material-technical base; presence and convenience of roads; transportation distance to education institutions, etc (Bilous, 2020). In general, within the Chernivtsi Territorial Community, there are institutions of general secondary education, institutions of pre-school educations, and also inclusive resource centers operate, institutions of pre-school education and institutions of higher education.

An important aspect in the development of education comprises parameters of dynamics of population and its sex-age structure, which form the specifics of the demographic process, which in turn determines the share of students in the age structure. The population of Chernivtsi city has continuously grown since 2002. As of 1 January 2019, 266,5 thou people lived in the city, which is almost 26 thousand more than in 2002 and almost 13 thousand more than in 2011 (Fig. 2). In the sex structure, women prevail (847 men per 1,000 women, which is 16 less compared with 2002). Age structure of the population is as follows: 0-14 years – 14.9%; 15-64 years – 71.9%; 65 and older – 13.2%, indicating regressive type of reproduction of the population.

The number of students in ISGE in Chernivtsi city starting from 2010-2011 school year has continuously grown. As of September 1, 2009, 27,649 students studied in these institutions of Chernivtsi city, which was over 5 thou students more compared with September 1 2020 (Fig. 3). Currently, 28,457 students are studying in the Chernivtsi Territorial Community, most of them (over 1,000 students) are in ZOSh (Middle School of General Education) of levels I-III: № 24 School named after Olha Kobylianska,

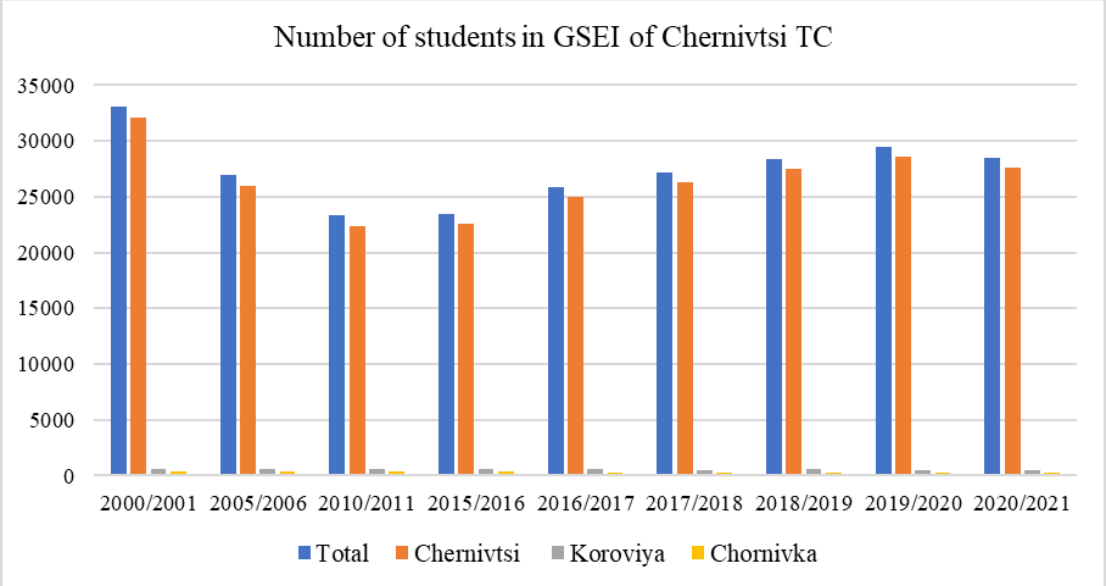

Fig. 2. Dynamics of number of population of Chernivtsi city

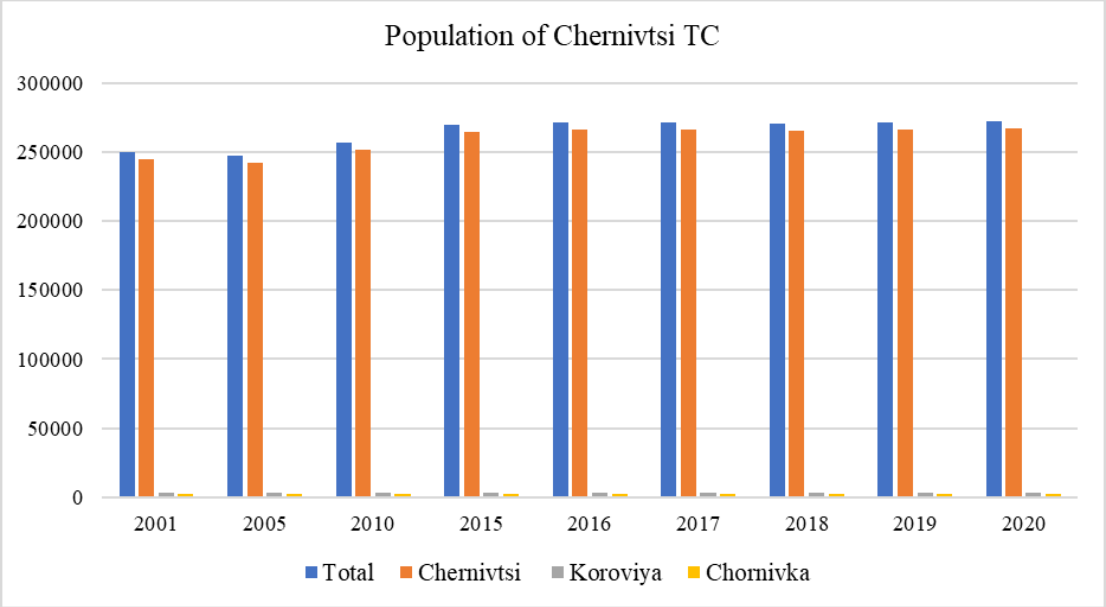

Fig. 3. Dynamics of the number of students in the institutions of general education in Chernivtsi city

ZOSh of levels I-III № 27, ZOSh of levels I-III №28, Chernivtsi ZOSh № 6, Chernivtsi Specialized School of levels I-III № 22, and the loweat number (less than 200 students) are in the Harmonia Private Specialized School of levels I-III, ZOSh of levels I-II №17, ZOSh of levels I-II №13, Chernivtsi Gymnasium №6 named after Oleksandr Dobry with teaching in Romanian, the Military and Sport Boarding Lyceum, ZOSh of levels I-III № 10, ZOSh of levels I-III № 40, located in the rural part of the city, Chernivtsi Specialized School of level I №29. According to the levels of education, the largest number of students studies at level II (13,064 students), and the least at level III (2,877 students).

An important element in the organization of high-quality education is the size of the class, which affects various constituents of educational space. The average class in the schools of the Chernivtsi Community comprises 27.3 students, and most optimum parameter ranges within 20-25 students (Kostashchuk & Bilous, 2014). It has to be noted that in the educational institutions of the Chernivtsi Community, the size of the groups is higher than average, and it also varies depending on the part of the city (central, rural, commuter towns, etc). The largest groups (over 35) are in 4 educational institutions, whereas the smallest (less than 20) are in 6 educational institutions. Only 6 institutions have optimum parameters of the groups, particularly: Chornivsky Training-Educational Complex (TEC), ZOSh of levels I-III - №40, Chernivtsi Gymnasium №6 named after Oleksandr Dobry, ZOSh of levels I-III stages №30, Koroviya ZOSh of levels I-III and the Chernivtsi Specialized School of level I №29.

One of the most important factors of optimizing secondary education is location of the institutions, and also accessibility to them by walking or riding. According to the sanitary norms, the radius of walking distance to secondary education institutions should be 2 km. Students who live at the distance more than 2 km away from the school should be provided with transport according to the regulations of the founder (founders) of the educational institution in correspondence with the current legislation. Transportation is carried out according to the designated plan of stops. The distance from accommodation to the gathering place for students at the stop should not exceed 500 m (Pro zatverdzhennia Sanitarnoho rehlamentu dlia zakladiv zahalnoi serednoi osvity, 2020).

To implement the goals, as already mentioned, we used Open Route Service, and also geoinformational systems ArcGIS and QGIS. In ArcGIS v.10.5 environment, particularly ArcMap app, we downloaded initial cartographic data: Shuttle Radar Topography Mission (SRTM), cosmic images in Natural Spectrum (Landsaat) and various raster tiles (OSM). Also, by applying Field Calculator, we have separately developed a geospatial set of data (Fig. 4), which included 721 linear objects of street network and courtyard passages (730.38 km) of the Community and 56 point objects of secondary education (Fig. 5 and 6). Every object was given an attribute, regarding its name, type, population living around it, and the number of students studying in it. Then, vector data were overlaid on the corresponding rasters.

Based on these data, using NeworkAnalyst tool, we developed graphs of the route network, with almost 5,000 binding and turning points. They will serve as

Table

Point_school

FID	Name	Area	Accessibility	Type	Num_Popul	Num_Pupil	Num_ZZSO	Adress	Shape *	Id	Name2	Degree
33	Gymnasium №5	10,206	0,812	gymnasium	51989	452	29	Dmytra Zagula str., 3	Point	0	#5G	
52	School №23	10,206	0,812	school I-level	51989	301	29	Dmytra Zagula str., 3	Point	0	#23	
22	School №4	10,112	0,805	school	53466	626	28	Shevchenka str., 16	Point	0	#4	I-III
29	Gymnasium №1	9,897	0,788	gymnasium	49282	623	21	Nezalezhnosti av., 68	Point	0	#1G	
0	School №1	9,816	0,781	school	48310	634	21	Eminesku str., 1	Point	0	#1	I-III
54	School №7	9,898	0,78	school I-level	49282	752	21	Nezalezhnosti av., 68	Point	0	#7	
31	Gymnasium №3	9,748	0,776	gymnasium	52438	409	28	Golovna str., 131	Point	0	#3G	
53	School №26	9,748	0,775	school I-level	52438	402	28	Golovna str., 131	Point	0	#26	
25	School №5	9,721	0,774	school	47840	846	24	Lesi Ukrainky str., 1	Point	0	#5	
40	Lyceum №4	9,633	0,767	lyceum	43155	964	18	Nebesnoi Sotni str., 18	Point	0	#4L	
44	Garmonija	9,633	0,767	education complex	43155	57	16	Nebesnoi Sotni str., 18	Point	0	Ljubystok	
9	School №20	9,603	0,764	school	49491	446	21	Glibova str., 21	Point	0	#20	I-III
11	School №24	9,564	0,761	school	48360	1183	17	Fizkul`turna str., 5	Point	0	#24	
8	School №2	9,539	0,759	school	48679	726	27	Golovna str., 87	Point	0	#2	I-III
37	Lyceum №1	9,545	0,759	lyceum	44735	323	22	Shtejnbarga str., 2	Point	0	#1L	
16	School №30	9,524	0,758	school	51785	447	23	Sherbanjuka str., 4	Point	0	#30	
39	Lyceum №3	9,287	0,739	lyceum	52246	434	23	Zalozec`kogo str., 13a	Point	0	#3L	
27	School №8	9,201	0,732	school	35807	585	20	Dzerzhyka str., 22	Point	0	#8	
49	School №9	9,19	0,73	school I-level	41839	484	22	L. Ukrainky str., 29	Point	0	#9	I
23	Jewish school №41	9,114	0,725	school	44230	347	20	Shkil`na str., 2	Point	0	JS#41	
32	Gymnasium №4	9,027	0,718	gymnasium	40574	629	19	Shepkina str., 2	Point	0	#4G	
15	School №3	8,885	0,707	school	46850	662	25	Hercena str., 36	Point	0	#3	
26	School №6	8,829	0,703	school	30757	1063	14	Komarova str., 26b	Point	0	#6	
38	Lyceum №2	8,617	0,686	lyceum	43305	232	25	L. Kobylyci str., 88a	Point	0	#2L	
4	School №14	8,595	0,684	school	41698	576	19	Shkil`na str., 3	Point	0	#14	I-III
12	School №25	8,596	0,684	school	33789	453	17	Ivana Mazepy str.	Point	0	#25	I-III
30	Gymnasium №2	8,4	0,668	gymnasium	43541	407	22	Golovna str., 73	Point	0	#2G	
51	School №35	8,4	0,668	school I-level	43541	248	22	Golovna str., 73	Point	0	#35	
2	School №11	8,387	0,667	school	25191	762	11	Pivdennokil`ceva str., 5	Point	0	#11	
34	Gymnasium №6	8,283	0,659	gymnasium	41140	152	18	A. Sheptyc`kogo str., 19	Point	0	#6G	
55	School №29	8,283	0,659	school I-level	41140	192	18	A. Sheptyc`kogo str., 19	Point	0	#29	
46	Nadija	8,015	0,638	private institution	18292	202	2	Moskovs`koi Olimpiady str	Point	0	Nadija	
35	Gymnasium №7	7,998	0,636	gymnasium	39629	752	21	Nezalezhnosti av., 88d	Point	0	#7G	
50	School №15	7,998	0,636	school I-level	39629	597	21	Nezalezhnosti av., 88d	Point	0	#15	
19	School №37	7,847	0,624	school	22061	622	3	Ivana Pidkovy str., 9	Point	0	#37	
1	School №10	7,74	0,616	school	22206	180	5	Gorihivs`ka str., 31	Point	0	#10	
41	Military lyceum	7,722	0,614	lyceum	26234	172	8	Lukovec`ka str., 29	Point	0	Military liceum	
18	School №33	7,685	0,612	school	33484	623	24	Heroiv Majdanu str., 152a	Point	0	#33	I-III
13	School №27	7,385	0,588	school	26416	1313	13	Vorobkevycha str., 19	Point	0	#27	
43	Ljubystok	7,345	0,584	education complex	27040	815	4	Rus`ka str., 228a	Point	0	Ljubystok	
42	Lider	7,226	0,575	education complex	22375	321	5	Berezhans`ka str., 25a	Point	0	Lider	
47	Solomon	7,199	0,573	private institution	25436	270	5	Korostyshevs`ka str., 6a	Point	0	Solomon	
10	School №22	7,026	0,559	school	21752	1438	9	Pivdennokil`ceva str., 17	Point	0	#22	I-III
20	School №38	6,784	0,54	school	18990	553	3	Jana Nalepky str., 3	Point	0	#38	I-III
45	Glorija	6,636	0,529	private institution	21594	18	11	Kovel`s`ka str., 25	Point	0	Glorija	
17	School №31	6,571	0,523	school	18229	758	0	Dibrovec`ka str., 5a	Point	0	#31	I-III
28	Beregynja	6,308	0,502	education complex	19846	237	3	Karbulyc`kogo str., 2	Point	0	Beregynja	
3	School №13	6,301	0,501	school	16370	151	3	Nemyrivs`ka str.,3	Point	0	#13	I-II
6	School №17	6,215	0,495	school	12037	87	5	Sokyrjans`ka str., 18	Point	0	#17	I-II
14	School №28	6,063	0,482	school	14141	1097	2	Rus`ka str., 257a	Point	0	#28	
7	School №19	6,009	0,478	school	25779	245	2	Hotyns`ka str., 23	Point	0	#19	I-III
21	School №39	5,866	0,467	school	18489	315	3	Karbulyc`kogo str., 4	Point	0	#39	
48	Chornivka school	5,761	0,458	education complex	1353	286	0	Chornivka, Golovna str., 13	Point	0	School of Chor	
5	School №16	5,297	0,421	school	17199	582	5	Bilorus`ka str., 77	Point	0	#16	
36	Korovija school	5,276	0,419	school	3171	522	0	Korovija, Shkil`na str., 1a	Point	0	School of Koro	
24	School №40	2,538	0,202	school	8442	182	0	Osinnja str., 58	Point	0	#40	I-III

Fig. 4. Attributive table with ranking according to accessibility parameters

benchmarks for establishing routes for walking and driving (Fig. 7).

Therefore, using Open Route Service and QGIS, we developed isochrones of 2-km zone of walking accessibility to the schools of secondary education of levels I and II-III for the Chernivtsi Local Community. Using QGIS Desktop, generalized data of the accessibility were overlaid on the map of the Chernivtsi Local Territorial Community with identified zones of walking accessibility.

After analyzing the map of walking accessibility to education institutions of the Chernivtsi Territorial Community, we identified the territories where the students need transport, and also territories with a quite dense arrangement of IGSE. The best arrangement of IGSE is in the central part of the city, and also in Prospect and Bulvar microdistricts, where several educational institutions are located within the radius of 2 km. Therefore, within the catchment area of School №4, Chernivtsi Gymnasium №3, Primary School № 26, Chernivtsi Gymnasium № 5, Chernivtsi Specialized School of level I № 23, there are 28 institutions, providing the students with a broader choice of education institution, and therefore increasing competition and quality of providing education services. At the same time, the worst situation is in ZOSh of levels I-III № 31, School №40, Koroviya ZOSh of levels I-III, Chornivsky TEC, for the number of IGSE there within the 2km zone, is 0, i.e. these institutions are the only ones within the 2 km-radius catchment area. On average, the number of IGSE within the 2 km zone of a certain institution is 14.7. Also, there are territories in Chernivtsi, where the students need transportation. The territories of Tsetsyno and Slobidka microdistricts are completely beyond the walking distance to IGSE. Partial coverage of walking distance zone is in microdistricts Dolishni Sherivtsi, Rohizna and Kalichanka (Fig. 8).

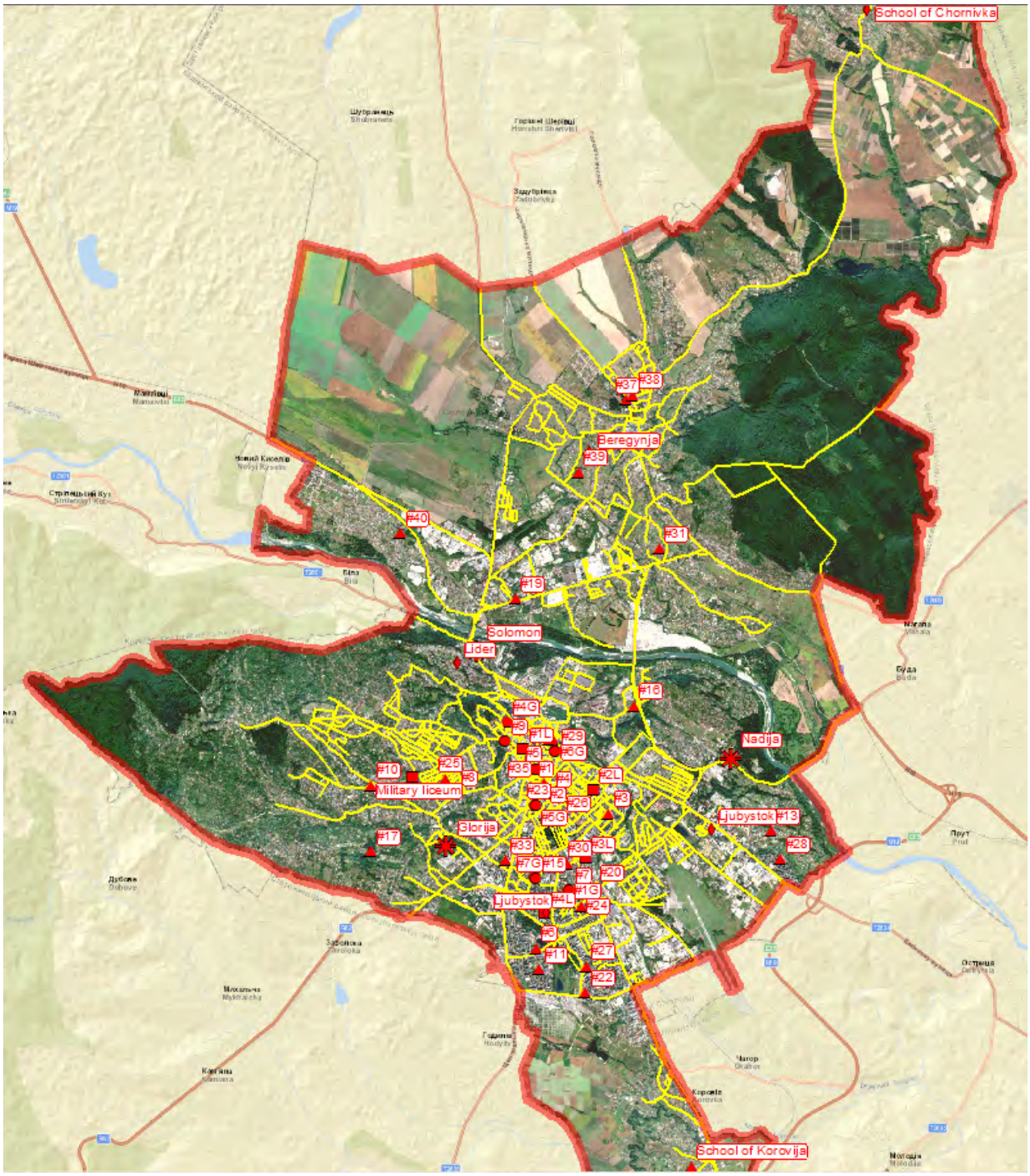

Fig. 5. View of the basic set of layers in ArcMap app

An important aspect of formation of a high level of knowledge in students at the current stage of development of education is specialized education and pre-specialized training, and gymnasiums with in-depth study of separate subjects. These institutions allow the students to better demonstrate their intellectual capacities. In the Chernivtsi Territorial Community, the walking accessibility to these education institutions greatly varies. In general, in Chernivtsi, there operate 5 lyceums and 7 gymnasiums. The zone of walking accessibility to those institutions covers the central part of the city and microdistricts Prospect and Bulvar. On the other hand, Chornivka and Korovia villages, Sadroga, Slobidka, Nova Zhuchka, Hraviton, Stara Zhuchka, Rohizna, Lenkivtsi and Kalichanka microdistricts are beyond the zone of 2 km zone of walking accessibility (Fig. 9).

In total, in Chenivtsi city, 1,567 students who live out of the zone of walking accessibility need to

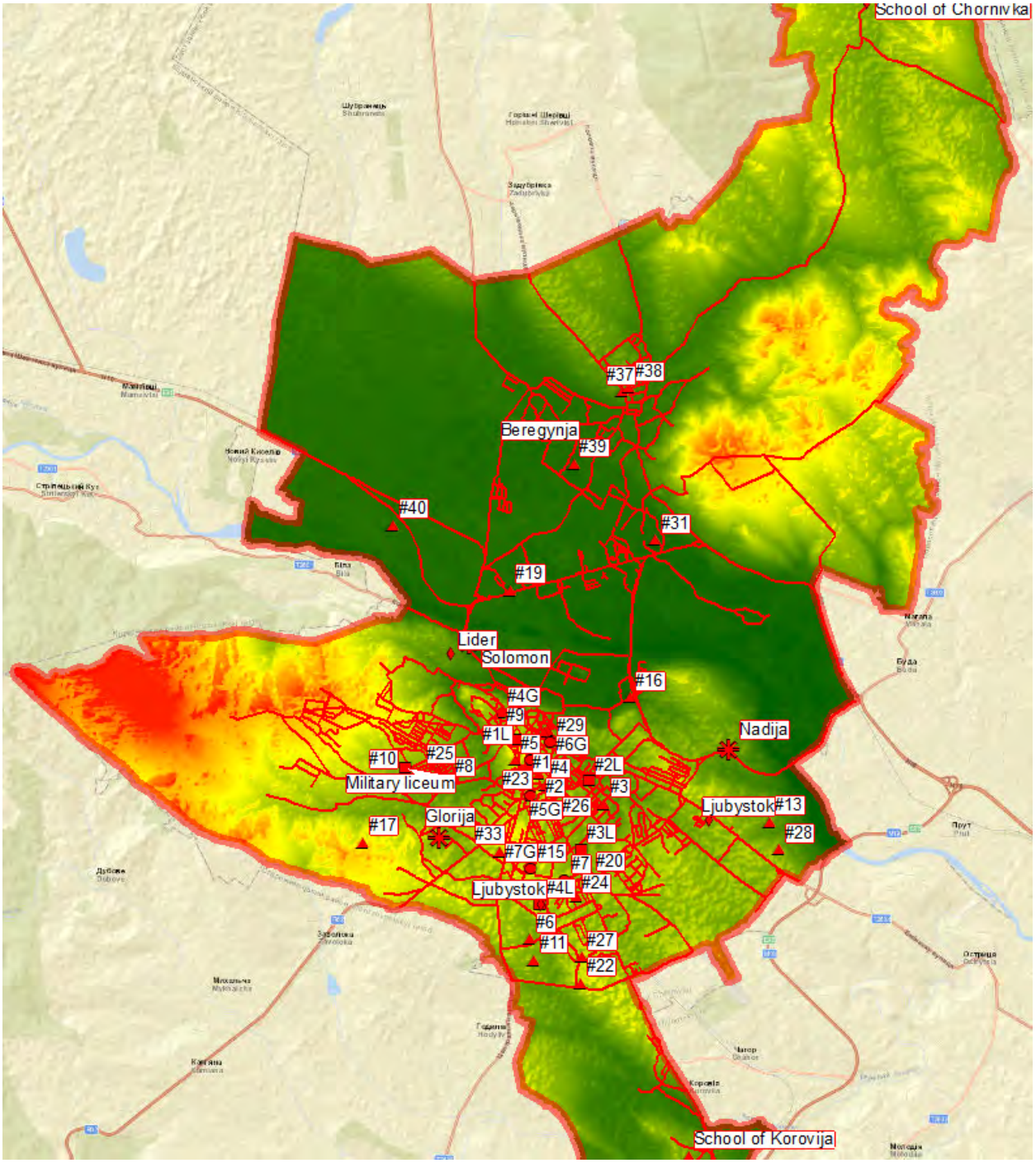

Fig. 6. Digital model of the area with vector layers, developed in ArcMap app.

be driven to schools. The children are transported by minibuses and trolleybuses of Chernivtsi. The highest number of students who need transportation, 180 children, comprises those studying in GSS №8 and gymnasium №5.

An important parameter of functioning of the institutions is the area of the zone of walking accessibility and the number of population living within its range. These parameters are important in the context of formation of number of students in the educational institutions. The area of the zones of walking accessibility to IGSE of the Chernivtsi Community ranges within 5.29 km^2 to 10.2 km^2. The greatest area of 2 km zone of walking accessibility, particularly more than 10 km^2 were determined for School №4, Chernivtsi Gymnasium № 5 and Chernivtsi Specialized School of level I № 23. On the other hand, 6 schools in the Chernivtsi Territorial Community have an area of accessibility of less than 6 km^2 (School №40, Koroviya ZOSh of levels I-III, School №16, Chornivsky TEC and School №39). Population in the zone of walking distance ranges 1,353 (Chornivsky TEC) to 53,466 people (School №4).

An important parameter in research on territorial

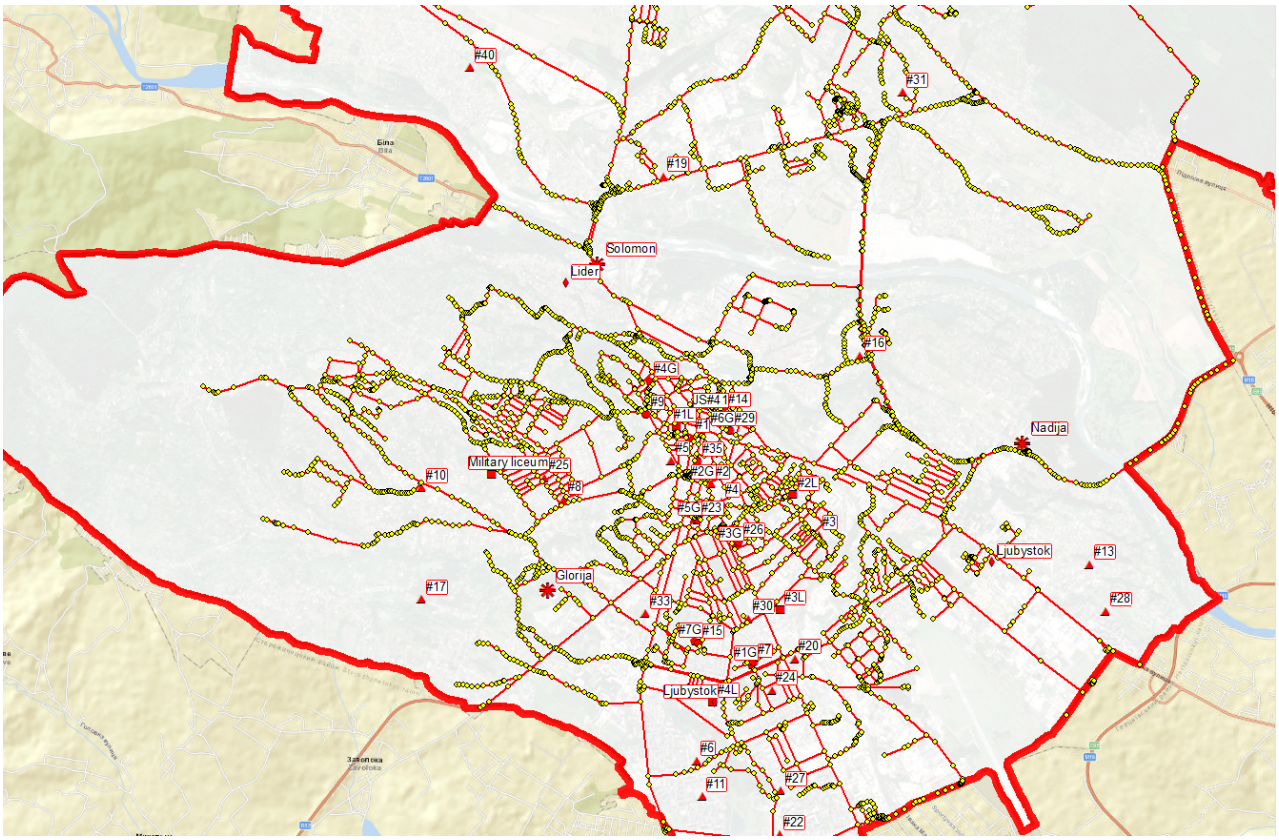

Fig. 7. Graphs of the road network

arrangement of the institutions of education is coefficient of accessibility, which we determined using Open Route web service. The parameter of accessibility may equal 0 (worst accessibility) to 1 (best accessibility). The parameter of accessibility to the educational institutions of the Chernivtsi Territorial Community is quite high (over 0.75) for 16 institutions (School №30, ZOSh №2, Chernivtsi Lyceum №1, Chernivtsi ZOSh № 24, Chernivtsi ZOSh № 20, Lyceum №4, Harmonia Private School, School №5, Chernivtsi Gymnasium №3, Primary School № 26, School №1, Chernivtsi Gymnasium №1 named after T. H. Shevchenko, School №7, School №4, Chernivtsi Gymnasium № 5, Chernivtsi Specialized School of level I № 23), and the lowest parameter was obtained for 8 institutions (Schools №40, №16, №17, №19, №28, №39, Koroviska ZOSh of levels I-III and Chornivska TEC) – less than 0.5. The average parameter of accessibility to the educational institutions of the Chernivetska Territorial Community is 0.65.

A special aspect in research of geospatial arrangement of educational institutions is determining local specific of walking accessibility. For this purpose, we selected one of the most populated housing districts of the Community – the Pivdenny Housing Estate, within which there are 4 institutions of general education. This stage allowed us to distinguish the shortest routes to school, and therefore to chose the smallest distance – 0.5; 1.0; 1.5 and 2.0 km (Fig. 10).

The provided cartographic model presents distance from the IGSE taking into account streets and courtyard passages, and also the extent of capacity to pass through. At the same time, there is a distinct ramification of 500 m zone along the highway streets and communication lines adjacent to the IGSE. Quite disproportionate is the coverage of peripheral parts of the housing estate, though they are included in the 2 km zone.

Conclusions

In the process of reforming the education sphere, an important aspect is the accessibility of high-quality education for all participants of the education process. Researches on this problem is impossible without modern scientific-informational approaches. Therefore, the geoinformation approach made it possible to plan and project the general education network of territorial communities, making it possible to analyze optimum arrangement of IGSE in the territorial community, and at the same time determine the territories from where the students should be transported. The advantages of GIS are the speed, reliability and accuracy of the obtained data, complexity of the selection, analysis and visualization, while the overlay properties of GIS apps allow

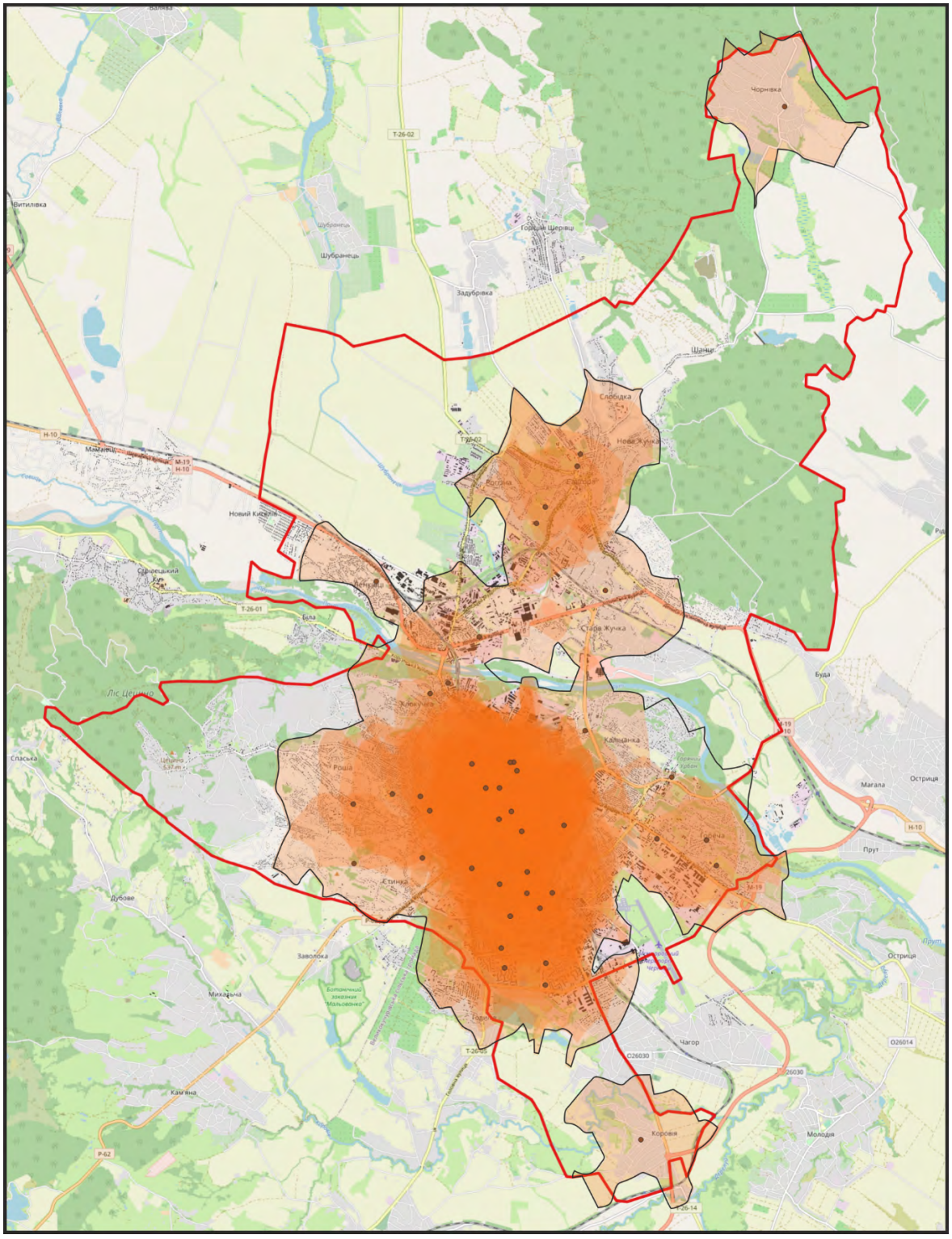

Fig. 8. 2 km zone of walking accessibility to a IGSE in Chernivtsi City Territorial Community

consideration of numerous factors. The disadvantages of using such an approach are dependency on relevant statistical data, as well as initial geospatial data.

Web-service Open Route allowed us to develop isochrones of walking accessibility of the students and analyze the arrangement of IGSE of the Chernivtsi City Territorial Community. Complex involvement of QGIS and ArcGIS gave an opportunity to create a data base and visualize the obtained data as cartographic models so as to determine the coefficient of accessibility to the institutions, analyze their geospatial arrangement and determine territories according to different levels of accessibility.

The observed territorial disproportions in the provision of equal access of the students to high-quality education, on the example of Chernivtsi

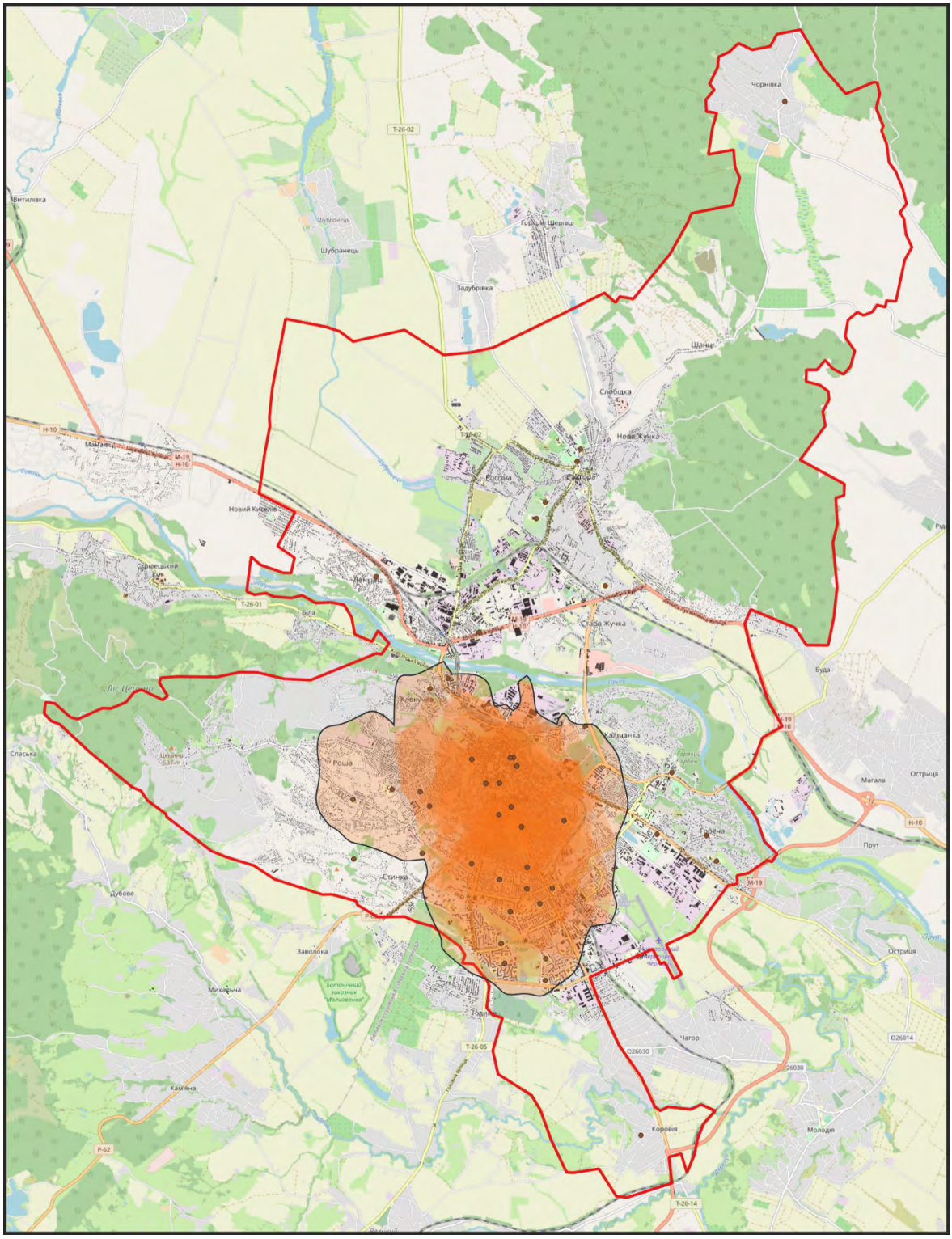

Fig. 9. 2 km zone of walking accessibility to lyceums and gymnasia of Chernivtsi City Territorial Community

Territorial Community, allowed us to understand that there are notable differences between the central part of the city and its rural zones and villages included in the city community. This problem is relevant for almost all communities established around large cities.

The proposed coefficients of accessibility to education institutions and methods of their determining using GIS technologies have essential practical significance during projecting the education network. Such research is especially relevant for analysis and re-planning of education networks of territorial communities that include over five settlements of various sizes and with various populations in them. Using GIS-technologies, we determined territories of the Chernivtsi Territorial

Fig. 10. Walking distance to institutions of secondary education in the Pivdeny housing estate

Community located beyond the 2 km zone of walking distance, and also accessibility to each IGSE in the Community. The coefficient of accessibility in Chernivtsi City Territorial Community ranges 0.2 to 0.8, and the average parameter of accessibility is 0.65. This indicates that most part of the territory of the Chernivtsi City Territorial Community is within walking accessibility distance.

References

Bilous, J. (2020). Optimization of the network of general secondary education institutions in the conditions of decentralization: geographical aspect. Human Geography Journal, 28, 64–70. Doi: 10.26565/2076-1333-2020-28-07

CapassoDaSilva, D., King, D. A., &Lemar, S. (2019). Accessibility in Practice: 20-Minute Cityas a Sustainability Planning Goal. Sustainability, 12(1), 129. Retrieved from https://doi.org/10.3390/su12010129

Colclough, J. G., & Owens, E. (2010). Mapping pedestrian journey times using a network-based GIS model. Journal of Maps, 6(1), 230–239. Retrieved from doi: 10.4113/jom.2010.1075

Dzhaman, V. O., Zaiachuk, M. D., & Zaiachuk, O. H. (2010). Vyznachennia heohrafichnoho tsentru terytorii ta otsinka transportno-heohrafichnoho polozhennia administratyvnykh tsentriv Chernivetskoi oblasti. [Ascertainment of the Territory Geographical Center of and Assessment of Transport-Geographical Disposition in the Chernivtsi Region Administrative Centers]. Scientific Bulletin of Chernivtsi university, (527: Geography), 95-100. (In Ukrainian)

Ghosh, S., Guchhait, S. K., &Sengupta, S. (2018). Measuring Spatiality in Infrastructure and Development of High School Education in Hooghly District of West Bengal, India. Space and Culture, India, 6(1), 51-71. Retrieved fromhttps://doi.org/10.20896/saci.v6i1.331

HeiGIT. (2020). OpenRouteService route planner - directions, isochrones and places. https://maps.openrouteservice.org/.

Honcharov, D.O., & Oliinyk, O.V (2016).Dosvid vprovadzhennia heohrafichnykh informatsiinykh system u sferi planuvannia i upravlinnia terytoriieiu naselenykh punktiv. [Experience in implementing geographic information systems in the field of planning and management of the territory of settlements]. Materials of reports: III international scientific-practical conference "Geoinformation technologies in the territorial management", 32-36. Odesa, ORIDU. (In Ukrainian)

Ishchuk, O. O., Korzhnev, M. M., & Koshliakov, O. Ye. (2003). Prostorovyi analiz i modeliuvannia v HIS. [Spatial analysis and modeling in GIS]. Kyiv: Kyiv University Publishing and Printing Center. (In Ukrainian)

Kostashchuk, I.I. & Bilous, Yu.O. (2014). Suspilno-heohrafichni chynnyky, shcho vplyvaiut na yakist znan uchniv (na prykladi Chernivetskoi oblasti). [Socio-geographical factors that affect the quality of students' knowledge (on example of Chernivtsi oblast)]. Proceedings of the international scientific-practical conference: "Geography, cartography, geographical education: history, methodology, practice".Chernivtsi: Rodovid Publishing House. (In Ukrainian)

Lakhotia, S., Lassarre, S., Rao, K. R., &Tiwari, G. (2020). Pedestrian accessibility and safety around bus stops in Delhi. IATSS Research, 44(1), 55–66. Retrieved from https://doi.org/10.1016/j.iatssr.2019.07.001

Leiberiuk, O. (2017). Transportna dostupnist naselennia do tsentriv hospitalnykh okruhiv (konkretnyi analiz na prykladi Chernivetskoi obl.). [Transport accessibity of the population to the centers of hospital district (a concrete analysis on the example of Chernivtsi region)]. Scientific Bulletin of KSU Series Geographical Sciences, 7, 62-68. (In Ukrainian)

Loidl, M., Wallentin, G., Cyganski, R., Graser, A., Scholz, J.,&Haslauer, E. (2016). GIS and transport modeling-strengthening the spatial perspective. ISPRS Int. J. Geo-Information, 5 (6), 84. Retrieved from https://doi.org/10.3390/ijgi5060084.

Martínez-Jiménez, E., &Salinas-Pérez, J. A. (2019). Accessibility to culture and education. Educative city of Córdoba (Spain). Journal of Maps, 15(1), 39–45. Retrieved from https://doi.org/10.1080/17445647.2019.1575776

Pro zatverdzhennia Sanitarnoho rehlamentu dlia zakladiv zahalnoi serednoi osvity: nakaz Ministerstva okhorony zdorovia Ukrainy vid 25.09.2020. № 2205. (2020). [On approval of the Sanitary Regulations for general secondary education institutions]. Retrieved from https://zakon.rada.gov.ua/laws/show/z1111-20#Text [in Ukrainian]

Qian, C., Zhu, D., Zhou, Y., & Chen, J. (2018). Measurements of Pedestrian Friendliness of Residential Area: A Case Study in Hexi District of Nanjing. Sustainability, 10(6), 1993. Retrieved from https://doi.org/10.3390/su10061993

Ridosh, Ye. (Ed.). (2020). Chernivetska terytorialna hromada [Chernivtsi territorial community]. Decentralization in Ukraine. Retrieved from https://decentralization.gov.ua/newgromada/4918. (in Ukrainian)

Ridosh, Ye. (Ed.). (2021). Sektor osvita. [Education sector]. Decentralization in Ukraine. Retrieved from https://decentralization.gov.ua/education (in Ukrainian)

Rudenko, L., Kozachenko, T., Liashenko, D., Bochkovska, A., Dyshlyk, A., Chabaniuk, V., & Putrenko, V. (2011). Heoinformatsiine kartohrafuvannia v Ukraini: kontseptualni osnovy i napriamy rozvytku [Geoinformation mapping in Ukraine: conceptual fundamentals and directions of development (L. Rudenko, ed.)]. Kyiv, Nauk. opinion. (In Ukrainian)

Sayed, A., Romani, F.I., & Hesham, A.H. (2017). GIS-BasedNetworkAnalysisfortheRoadsNetworkoftheGreaterCairoArea. Proceedings of the International Conference on Applied Research in Computer Science and Engineering ICAR'17, Lebanon, 2144. Retrieved from http://ceur-ws.org/Vol-2144/paper2.pdf

Shypulin, V.D. (2014). Osnovy HIS-analizu. [Basics of GIS analysis]. Kharkiv: NUUE. (in Ukrainian)

Ventura-Fernández, J., González-Relaño, R., & Gavira-Narváez, A. (2017). Accessibility of rail trails in Huelva, Andalusia (Spain). Journal of Maps, 13 (October), 62–66. Retrieved from doi: 10.1080/17445647.2017.1323033