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THE EVALUATION OF ACCESSIBILITY TO HOSPITAL INFRASTRUCTURE AT REGIONAL SCALE BY USING GIS SPACE ANALYSIS MODELS: THE NORTH-WEST REGION, ROMANIA

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ABSTRACT. – The Evaluation of Accessibility to Hospital Infrastructure at Regional Scale by Using GIS Space Analysis Models: the North-West Region, Romania. Easy access of the population to hospital infrastructure represents one of the main preoccupations of local and national authorities in the attempt to increase the degree of deliverance of quality medical services. The analysis of territorial distribution of various hospital categories- city, clinical, teaching, emergency hospitals- has revealed some areas of deficit in what regards the availability of various types of medical assistance. Identifying the areas of deficit from the point of view of accessibility to hospital infrastructure is carried out by means of a GIS model of space analysis (Cost Surface Modeling type) based on the calculation of access time from any location in the territory to the nearest hospital taking into consideration the vector databases (access ways, hospitals etc.), assignment (speed of motion on access ways, hospital type) and raster (access time).

Keywords: *hospitals, accessibility, GIS, spatial analysis, regional approach*.

1. INTRODUCTION

Ensuring access to health services is a key objective of social policies at the level of the European Union. According to strategic documents that guideline the health system reform in Romania, accessibility to medical care services is determined by the convergence between offer and demand of such services and disparities regarding accessibility are generated by intrinsic factors (heterogeneous quality of services of the same type), economic, social and geographical factors (Cocean P., 2004). Despite the statistics regarding the state of health in Romanian (indicating significant disparities in comparison with other EU countries)and despite the issuing of various reports which have voiced the need for a health system that is centered on patient needs(Vlădescu et al., 2010, pp. 87 - 96, Vlădescu et al., 2010, pp. 89 - 99), the action taken at governmental level point more in the direction of obtaining economical efficiency by reducing costs (Vlădescu and Astărăstoaie, 2012, pp. 89 - 99).

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One of the recent actions in this respect has been the dissolution of a number of hospitals that had proven unprofitable from an economical point of view (Decree no. 303/ 2011) and which were not able to close contracts with the National Health Insurance Agency (Decree no. 345/2001).

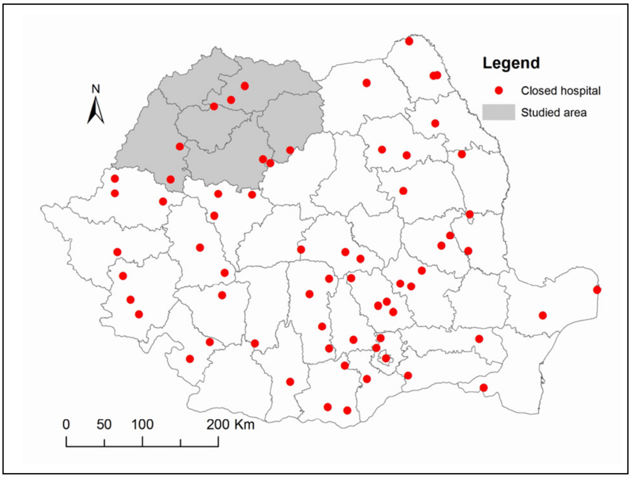

Fig. 1. Hospitals closed in Romania, according to Government Decree (H.G.) no. 345/2011.

Following the enforcement of this piece of legislation, 67 hospitals were dissolved in the entire country summing up to a total of 9200 hospital beds (The National Strategy of Hospital Rationalization, 2011). Excessive centralization in the Romanian healthcare system has inhibited some hospitals' possibility to become centered on particular healthcare services which could make them more competitive and compensate for deficit in other domains. Seldom are initiatives enacted in a manner that leads to the emergence of new hospitals which would, in turn, help relieve the pressure occurring in some units overused as a consequence of inadequate distribution throughout the territory (for instance the establishment of the Oncology Centre in Oradea, December 2012).

The current study has been carried out for the North-West Region, one of the most developed regions in Romania, with a population of2.495.247 inhabitants (according to the Population and Dwellings Census of 2011). This region includes six counties and is served by 57 hospitals (Table 1).

The current study attempts to analyze the space accessibility of hospitals in the North-West Region of Development at the level of year 2012, i.e. following the enactment of the previously mentioned piece of legislation.

From a terminological point of view there is need for operating the distinction between two terms associated to the analysis carried out: access to medical services (Soitu et al., 2013, pp. 123 – 133) and accessibility to specialty infrastructure (hospitals in this case). The former term refers to the legal right awarded to citizens to benefit from medical assistance. The latter term, accessibility, refers to the technical, spatial and temporal conditions that easily influence the ease with which a patient can reach a certain hospital.

The quantification of this complex of conditions is often made in relation to costs, distance and time in which the conveyance to a certain hospital can be made.

Accessibility is of utmost importance especially as approximately 30% of the population turns to hospital medical care every year (the Centre for Health Policies and Services, 2002) and 9% of the population turns to emergency hospital medical care every year (idem).

Table 1.

Statistical data regarding number of hospitals, population and localities in counties of the North-West Development Region

County	No. of inhabitants	No. of Hospitals	No. of units of Territorial Administration	No. of localities	No. of localities with hospitals
Bihor	549752	12	100	456	7
Bistrița-Nasaud	277861	5	62	249	4
Cluj	659370	19	81	434	7
Maramureș	461290	10	76	246	6
Sălaj	217895	6	63	289	4
Satu Mare	329079	5	65	234	3
Total	**2495247**	**57**	**447**	**1908**	**31**

The evaluation of population accessibility to various types of hospitals is a recurrent issue in studies regarding territorial administration and in studies investigating the efficiency of the healthcare system. Thus, comparative studies have been carried out analyzing the accessibility as its is perceived by the population and the accessibility models issued by hospitals using GIS techniques (Fone et al., 2006, pp. 16 - 25), studies regarding the access of the population to specialized hospital services by determining travel time by the isochrones method (Patel et al., 2007, p. 12),urban accessibility of medical services (Guagliardo, 2004, pp. 273 - 283, Ohta et al., 2007, pp. 687 - 698, Apparicio et al., 2008, pp. 1 – 13, Simões and Almeida, 2011, pp. 25 - 29), accessibility of primary medical services (Munoz and Källestål, 2012, pp. 40 - 50), the multi-dimensional approach to accessibility to medical services and the relationship between the perception of accessibility to these services and the social and economic status of the inhabitants (Comber et al., 2011, pp. 44 - 54). Other authors have approached aspects of cost and quality regarding accessibility of the population to medical services (Tanke, 2012, pp. 282 - 287) or of regional accessibility of population to basic commercial services (Salze et al., 2011, p. 2).

Aspects regarding the equity of accessibility from the perspective of travel time have been tackled by Christie and Fone, (2003, pp. 344 - 350) with respect to various age groups of the population served by hospitals at regional level (in Wales Region).

Kalogirou and Foley, 2006, (pp. 52 - 68) propose a study methodology of hospital accessibility in which a number of different factors are included such as hospital size (number of hospital beds) available road infrastructure and potential (the demographical size of the localities). The two authors have accomplished a vector analysis of the road infrastructure with the purpose of calculating travel time from the centre of localities to the hospitals, thus forwarding a formula for the evaluation of accessibility (SAM – Spatial Accessibility Measure).

Studies regarding accessibility to hospital infrastructure which emphasize spatial analysis and mathematical modeling as main methodologies for research have been carried out by Sherman (2005, pp. 24-46), Gu et al. (2010, p. 17) using only vector databases and by identifying the relationships of dependence between population and hospital unit as a support for spatial analysis identifying accessibility. More recently, Pedigo and Odoi (2010, pp. 924 - 930), tackle the problem of accessibility to hospital units specializing in cardio-vascular emergencies by using network analysis and euclidian models of evaluation of travel time. GIS techniques regarding access to medical services have been employed in numerous studies, with various work methodologies (Higgs, 2004, pp. 119 - 139), both in the case of analyses on structures of raster types as well as on vector type analyses.

The current study has been conceived and carried out as a complex model of spatial analysis by means of geo-informational software (well known due to their high rate processing abilities of databases with reference to territory) and the interpretation of data by means of spatial analysis equations.

2. METHODOLOGY

The proposed methodology of the present paper emphasizes the exploitation of vector and raster database structures of GRID type by means of a series of singular models of spatial analysis that have been synthesized in a single complex model the main purpose of which is the scoring and representation of the degree of accessibility to hospital infrastructure from any point on the surface of the territory under scrutiny.

2.1. The G.I.S. database

The database required in the process of spatial analysis has been established on the basis of thematic layers in vector and raster format, comprising access ways, building areas, hospitals etc., structured on three main types (primary, derived and modeled databases, Bilaşco, 2008, p. 38), depending on the manner of their exploitation in the structure of the final model (Tab. 2).

Table 2.

The G.I.S. Database Structure

Name	Type	Structure	Attributes	Major Category
Roads	vector	line	Road type, maximum speed	Primary
Built-up area	vector	polygon	Name	Primary
Hospitals	vector	point	Hospital type, code, address	Primary
UTA	vector	polygon	Name, number of inhabitants	Primary
Travel speed on road types	raster	GRID	min/m^2	Modeled
Travel speed on road types	raster	GRID	minutes	Modeled
Access time to emergency hospitals and non-emergency hospital types	raster	GRID	minutes	Modeled
Scoring of access to emergency hospitals and non-emergency hospital types	raster	GRID	Scoring grades	Derived
Access to hospitals	raster	GRID	Scoring grades	Modeled

The primary database (roads, built-up areas) represent the development foundations of any GIS spatial analysis model and has been carried out on the basis of map information (vectorized on the maps on a scale of 1:50000), representing the databases of utmost importance in the evaluation process of accessibility to medical infrastructure in the territory under analysis.

The accessibility model is based on the maximum legal speed on certain types of roads; therefore they have been integrated in the modeling process as linear vector type structures having as main attributes the type of road and speed for each type.

Present day legislation establishes the maximum speeds depending on the road category (European, national, county, communal road) and the built-up area sections that they cross (Table 4). In order to identify the road sections which cross built-up areas, as early as the phase of setting up the primary database, we have resorted to the spatial analysis type overlay vector-vector (road/built-up area) using the Identity function incorporated in the geo-informational ArcGIS program (fig. 2).

The database representing the hospitals has been carried out considering the manner in which it is used within the model but also depending on the requirements of the ArcGIS program, which is used to model territorial accessibility.

The identification of hospitals was carried out based on available public data and they were spatially represented in the form of a vector-point thematic layer, thus being able to identify a number of 57 hospitals grouped in two major categories: emergency hospitals and non-emergency hospitals, with various other subcategories for each major type. The main component of the attribute database for the identified hospitals is represented by the code corresponding to each subcategory to which each hospital belongs (Table 3).

Table 3.

The structure of the attribute database and the location of hospital categories

Category	Subcategory	Code	Number	Location
Emergency hospitals	County emergency hospital	1	4	Zalău, Baia Mare, Satu Mare, Bistrița
	Clinical emergency county hospital	11	2	Cluj-Napoca, Oradea
	Clinical emergency hospital	111	1	Oradea
	Military emergency hospital	12	1	Cluj-Napoca
	Clinical emergency children's hospital	1112	1	Cluj-Napoca
	Cardio-vascular emergency hospital	1111	1	Cluj-Napoca
Non-emergency hospital types	Clinical hospital	112	1	Oradea
	Clinical teaching hospital	1121	1	Cluj-Napoca
	Municipal hospital	2	10	Sighetu Marmației, Dej, Gherla, Turda, Câmpia Turzii, Carei, Oradea, Salonta, Beiuș, Marghita
	Municipal clinical hospital	211	1	Cluj-Napoca

Category	Subcategory	Code	Number	Location
	City hospital	3	9	Sighetu Marmaţiei, Negreşti-Oaş, Şimleu Silvaniei, Jibou, Beclean, Târgu Lăpuş, Beclean, Huedin, Aleşd
	Chronic illnesses hospital	4	1	Crasna
	Pneumology hospital	5	2	Satu Mare, Baia Mare
	Tuberculosis prevention clinic	51	1	Ilişua
	Clinical pneumology hospital	52	1	Cluj-Napoca
	Psychiatry hospital	6	4	Ştei, Nucet, Borşa (CJ), Cavnic
	Recovery hospital	7	1	Borşa (MM)
	Clinical recovery hospital	71	2	Cluj-Napoca, Oradea
	Private hospital	8	6	Zalău, Oradea, Satu Mare, Baia Mare (2), Bistriţa
	Private centre for recovery, treatment and care	81	1	Zalău
	Penitentiary hospital	10	1	Dej
	Clinical hospital for infectious diseases	151	1	Cluj-Napoca
	Oncology hospital	17	1	Cluj-Napoca
	Clinical hospital for urology and renal transplant	30	1	Cluj-Napoca
	Hospital for infectious diseases, dermatology, venerology and psychiatry	152	1	Baia Mare
	Hospital for gastro-enterology and hepatology	31	1	Cluj-Napoca

The modeled and derived databases are represented by structures resulting from the accomplishment of intermediary models subjected to a logical diagram, in the present case subsequently identified with the raster cost data, access time to various hospital types, where the raster represents the deficit areas from the point of view of access etc.

2.2. Spatial analysis

Following the analysis of the database and considering the complexity of the structure in the final model (Fig. 2) we have decided to carry out the spatial analysis as two models (the calculation of access time to hospital infrastructure, in minutes, and identifying the areas of deficit from the point of view of access to hospital infrastructure for the two types of hospitals using the scoring technique), each displaying its own logical structure.

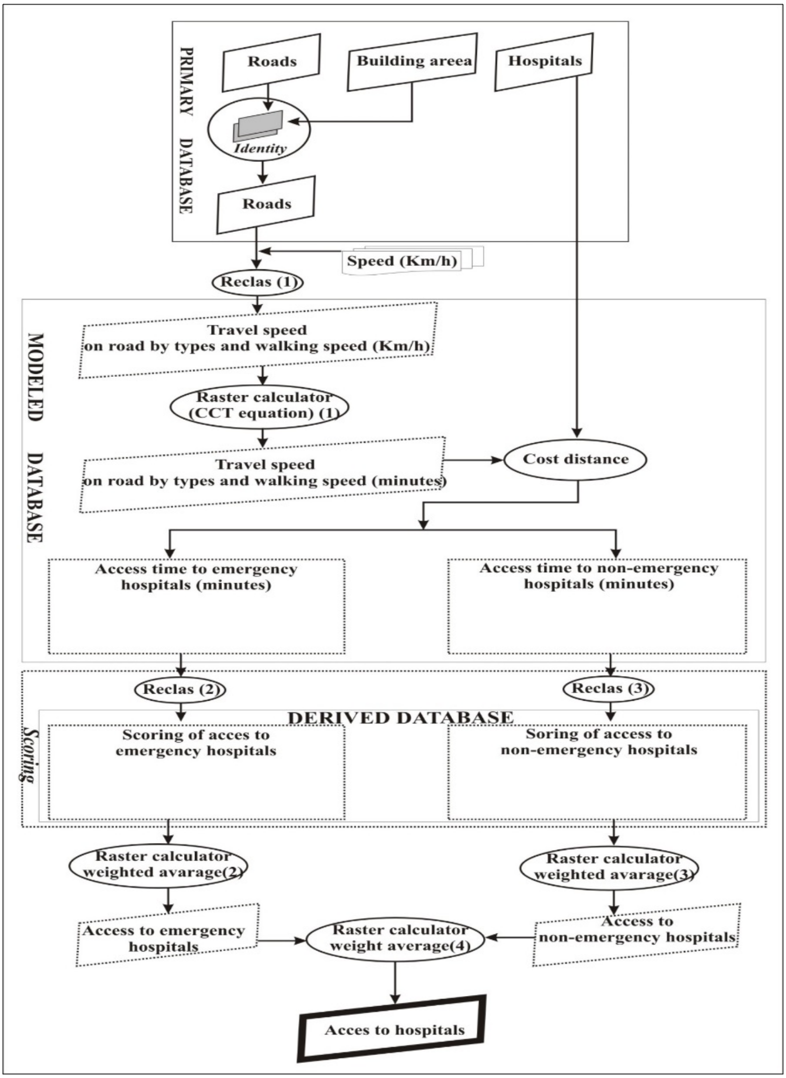

Fig. 2. The structure of the spatial analysis model.

3. RESULTS AND DISCUSSIONS

3.1. Modeling accessibility of hospitals

Most studies regarding accessibility and access time to various territorial infrastructures (Sherman, 2005, pp.24 - 46, Gu, 2010, p. 17, Munoz, 2012, pp. 40 - 50, Salze, 2011, p. 2) rely on vectorial models of analysis and representation of spatial reality as their work foundations.

These types of models can only be used in for identifying access time between different punctual locations connected through networks (roads) of vector type.

By means of the proposed model we aim at calculating access time in each point of the territory under scrutiny while considering the maximal travel speed on various road types as well as the average walking speed of a person on surfaces where there are no roads available.

The methodology for carrying out the model presupposes the use of raster specific databases of GRID type and their analysis by means of the function cost distance ArcGIS.

In the process of spatial analysis we have employed primary databases represented by roads in vector format that have been converted to raster format based on attribute database which represented the maximum travel speed, with a spatial resolution of the resulting raster of 10 m. All the cells of the raster that were not identified with a road network have been attributed a travel speed of 6 km/h. In choosing the resolution of the raster, the average 10 m width of a typical road was taken into consideration; in choosing the travel speed on surfaces with no vehicle access the average walking speed of a person was taken into account.

Using the cost distance function to calculate access time can only be implemented after the accomplishment of a raster with a value of the cell reflecting the time spent to traverse the respective cell at a particular speed, the so-called cost raster, together with the reference points represented by hospitals in relation to which the calculation of the access time in minutes will be carried out by summing up the value of the cell corresponding to the nearest reference point.

The main factor in modeling accessibility is represented by the creation of the database type raster GRID a cost raster. In order to model the cost raster database we have used the equation forwarded by Julião (1999), Drobne (2003, pp. 89 - 96, 2005, pp. 537 - 542), Drobne et al., 2005, pp. 213 - 218.

$$CCT = \frac{PS * 60}{TS * 1000}$$

CCT – cell crossing time (minutes), PS – pixel size, TS – travel speed (km/h)

Implementing the calculation equation in the GIS environment has been carried out by using the geo-informational ArcGIS program, more specifically, the raster calculator function based on a raster representing the maximum travel speed resulting from the conversion of the road network, for each cell:

(10 * 60) / ("speedfin" * 1000)

where: 10 – raster resolution, speedfin – raster representing maximum travel speeds.

The result of the equation is represented in the modeled raster type database which represents the cost raster with cell traversing speeds in minutes, varying according to travel speeds and representing one of the entry elements in the final accessibility model.

Table 4.
Maximum travel speed and cell traversing time depending on road type

No.	Road type	Travel speed Km/hour			
		Built-up areas		Outside localities	
		Travel speed	Cell crosing time (minutes)	Travel speed	Cell traversing time (minutes)
1	European road	50 / 70	0.012/0.0085	100	0.006
2	National road	50	0.012	90	0.0066
3	County road	50	0.012	90	0.0066
4	Communal road and service roads	30	0.02	30	0.02
5	-	6	0.01	6	0.01

The second factor that makes up the primary entry database to the structure of the accessibility model is symbolized by the point vector representing territorial identification of hospital units. The territorial identification of hospital units has been carried out by collecting GPS coordinates where possible as well by identification at street and postal box level. For increased ease in the retrieval of this database in the final model we have accomplished an attribute database based on codes and hospital categories (table 3). The databases representing the cost raster and the spatial identification of hospital units are the main elements in the calculation of access time in minutes using the cost distance function, which, according to ESRI, makes the calculation of the less cumulative cost starting from one or several origins and travelling through a cost surface.

For the mapping and spatial identification of territories with varying degrees of accessibility to emergency hospital infrastructure (Fig. 3 a, b) we have employed reference values depending on current Romanian legislation (Law no. 95/2006). Granting qualified first aid in cases of emergency is organized in such a manner as not to exceed 8 minutes for qualified first aid crews in urban areas, 12 minutes for qualified first aid crews in rural areas, 15 minutes for emergency or intensive care units in urban areas, 20 minutes for emergency and intensive care units in rural areas.

Spatial identification of access time to non-emergency hospitals (Fig. 3c, 3d) has been carried out using reference values for access time, making the analysis on the following accessibility classes: 0-10 minutes, 11-30 minutes, 31-60 minutes, 60-120 minutes and over 120 minutes.

Emphasizing accessibility for each type of hospital separately has been carried out with the help of the methodology for quantitative evaluation of the results obtained. To this end, the surfaces for all the intervals situated between reference values used in mapping were calculated while extracting the average access time in minutes for the entire territory under scrutiny (table 5).

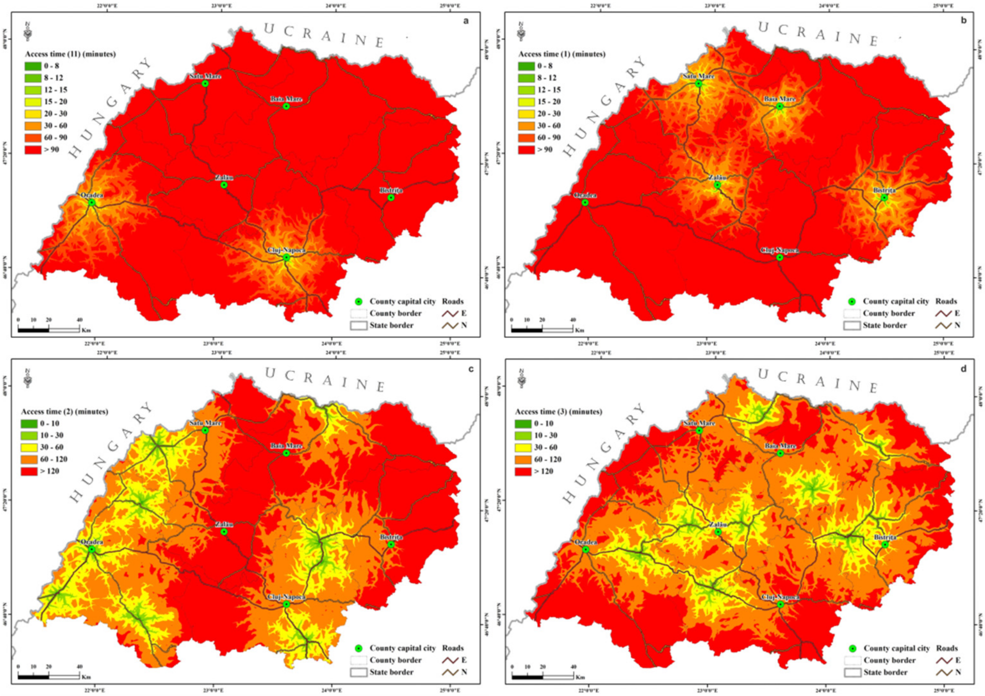

Figure 3. a. Access time to county clinical emergency hospital; b. Access time to county emergency hospital; c. Access time to municipal hospitals; d. Access time to city hospitals

Table 5.

Statistical values of accessibility

Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)	Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)
County emergency hospital	1	0 - 8	23.36	149.93	Tuberculosis Prevention clinic	51	0 - 10	5.81	252.85
		8 - 12	37.59				10 - 30	97.16	
		12 - 15	43.55				30 - 60	548.93	
		15 - 20	113.51				60 - 120	3465.08	
		20 - 30	417.38				>120	30046.93	
		30 – 60	2812.28						
		60 - 90	5058.52						
		>90	25657.74						
County clinical emergency hospital	11	0 - 8	12.38	194.43	Clinical hospital for pneumology	52	0 - 10	10.82	237.31
		8 - 12	20.34				10 - 30	141.38	
		12 - 15	24.57				30 - 60	856.69	
		15 - 20	61.22				60 - 120	3928.33	
		20 - 30	201.09				>120	29226.70	
		30 – 60	1601.53						
		60 - 90	3098.24						
		>90	29144.53						

Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)	Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)
Clinical emergency hospital	111	0 - 8	5.73	306.44	Psychiatry hospital	6	0 - 10	296.60	169.63
		8 - 12	10.59				10 - 30	1296.05	
		12 - 15	12.56				30 - 60	2792.67	
		15 - 20	32.38				60 - 120	4406.80	
		20 - 30	106.15				>120	25371.80	
		30 – 60	744.83						
		60 - 90	1466.60						
		>90	31785.07						
Military emergency hospital	12	0 - 8	6.65	237.31	Recovery hospital	7	0 - 10	57.17	375.82
		8 - 12	9.75				10 - 30	186.73	
		12 - 15	12.01				30 - 60	375.65	
		15 - 20	28.83				60 - 120	546.44	
		20 - 30	94.95				>120	32997.92	
		30 – 60	856.69						
		60 - 90	1631.64						
		>90	31523.38						
Clinical emergency children's hospital	1112	0 - 8	6.65	237.31	Clinical recovery hospital	71	0 - 10	319.62	194.43
		8 - 12	9.75				10 - 30	1601.53	
		12 - 15	12.01				30 - 60	3098.24	
		15 - 20	28.83				60 - 120	4118.68	
		20 - 30	94.95				>120	25025.85	
		30 – 60	856.69						
		60 - 90	1631.64						
		>90	31523.38						
Cardio-vascular emergency hospital	1111	0 - 8	6.65	237.31	Private hospital	8	0 - 10	802.80	125.04
		8 - 12	9.75				10 - 30	3557.11	
		12 - 15	12.01				30 - 60	6525.12	
		15 - 20	28.83				60 - 120	7215.39	
		20 - 30	94.95				>120	16063.49	
		30 – 60	856.69						
		60 - 90	1631.64						
		>90	31523.38						
Clinical hospital	112	0 - 10	10.08	306.44	Private centre for recovery, treatment and care	81	0 - 10	7.90	224.57
		10 - 30	157.33				10 - 30	113.58	
		30 - 60	744.83				30 - 60	686.83	
		60 - 120	3288.60				60 - 120	4117.04	
		>120	29963.07				>120	29238.58	
Clinical teaching hospital	1121	0 - 10	10.82	237.31	Penitentiary hospital	10	0 - 10	12.35	234.01
		10 - 30	141.38				10 - 30	163.12	
		30 - 60	856.69				30 - 60	702.08	
		60 - 120	3928.33				60 - 120	3960.07	
		>120	29226.70				>120	29326.30	
Municipal hospital	2	0 - 10	90.51	115.52	Clinical hospital for infectious diseases	151	0 - 10	10.82	237.31
		10 - 30	1232.05				10 - 30	141.38	
		30 - 60	5124.14				30 - 60	856.69	
		60 - 120	13000.85				60 - 120	3928.33	
		>120	14716.36				>120	29226.70	

Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)	Subcategory	Code	Interval (minutes)	Surface (Km²)	Average access time (minutes)
Clinical municipal hospital	211	0 - 10	10.82	237.31	Oncology hospital	17	0 - 10	10.82	237.31
		10 - 30	141.38				10 - 30	141.38	
		30 - 60	856.69				30 - 60	856.69	
		60 - 120	3928.33				60 - 120	3928.33	
		>120	29226.70				>120	29226.70	
City hospital	3	0 - 10	79.02	105.05	Clinical hospital for urology and renal transplant	30	0 - 10	10.82	237.31
		10 - 30	1018.86				10 - 30	141.38	
		30 - 60	4777.51				30 - 60	856.69	
		60 - 120	16439.02				60 - 120	3928.33	
		>120	11849.51				>120	29226.70	
Chronic diseases hospital	4	0 - 10	11.36	229.97	Hospital for infectious diseases, dermatology, venerology and psychiatry	152	0 - 10	10.27	258.60
		10 - 30	135.48				10 - 30	114.51	
		30 - 60	731.94				30 - 60	547.38	
		60 - 120	3906.89				60 - 120	2742.71	
		>120	29378.25				>120	30749.05	
Hospital for pneumology	5	0 - 10	20.70	226.06	Hospital for gastro-enterology and hepatology	31	0 - 10	10.82	237.31
		10 - 30	311.16				10 - 30	141.38	
		30 - 60	1344.80				30 - 60	856.69	
		60 - 120	4913.24				60 - 120	3928.33	
		>120	27574.01				>120	29226.70	

The analysis of accessibility differences brings to the surface the fact that almost all the categories of hospitals display obvious disparities. The calculation of the Gini index for surfaces associated to various time intervals displays values that generally exceed 0.7.Reduced values are present in the case of city hospitals (0.50) and municipal hospitals (0.48). The largest values of the Gini index are (between 0.82 and 0.84) are recorded in the case of clinical emergency county hospitals, military emergency hospitals, emergency children's hospitals, cardio-vascular emergency hospitals and clinical emergency hospitals. The most balanced distribution from the point of view of accessibility is recorded in the case of private hospitals (Gini index 0.40) and municipal hospitals (0.48).

From the point of view of surfaces associated with various time intervals, we notice that the largest values are recorded in the case of medium and high time intervals. This derives from the fact that the largest part of the territory is represented by surfaces to which access is carried out on foot and, consequently, when distance from access roads is longer, the access time increases significantly.

For average time (Table 6) of access to various types of hospitals the value of the Gini index decreases significantly (0.13). At county level, average values of access time display a relatively balanced distribution: Cluj 0.23, Bihor 0.23, Bistriţa 0.19, Maramureş 0.17, Salaj 0.17, Satu Mare 0.18. In absolute terms, though, average values are high, in some cases exceeding values of 400 minutes. At the same time, the differences between average intervention time within counties are large, as there are occasionally differences in access time four times greater between hospitals in various categories. The analysis of values on various categories of hospitals has revealed that the distribution of average access time values does not display large disparities; this is signaled by the values of the Gini index varying between 0.10 and 0.23. Nonetheless, as far as absolute values are concerned, the differences are significant both in the case of minimal time and in maximal time recordings and in the case of average access time as well.

3.2. Identifying areas of deficit from the point of view of access to hospital medical infrastructure

As can be deduced from the analysis of accessibility previously discussed, a large portion of the North-West Region displays deficiency as far as access to each hospital category under scrutiny is concerned. Identifying the areas of deficit from the point of view of access to medical hospital infrastructure has been carried out using GIS models based on quality scoring as the preferred method of spatial analysis.

3.2.1. Quality scoring of access time

The GIS methodology selected for identifying the areas with varying accessibility degrees throughout the territory, following the analysis of the modeled database obtained from the finalization of the accessibility model is the quality scoring of access time and their integration in GIS spatial analysis equations under the form of weighted average.

The necessity of adopting the methodology of quality scoring resides in the fact that the integration of access time as modeled grid type databases with concrete values, minutes, in GIS spatial analysis would lead to results that are extremely difficult to interpret and prone to error from the viewpoint of actual access time through their exaggeration resulting from the equation.

Scoring of access time to emergency hospital infrastructure has been carried out according to existing Romanian legislation, Law no. 95/14-th April 2006 which regulates the intervention time values in cases of emergencies and assigns quantitative grades in the interval 1-8 (1 being the minimal time of access- easy access; 8 being the maximal access time- difficult access) (Tab. 7). In order to evaluate accessibility to non-emergency hospital units scoring grades were assigned taking into consideration fixed time references, by assigning grades from 1-5 (1 being the minimal time of access- easy access; 5 being the maximal access time- difficult access (Tab. 7).

In the process of carrying out the spatial analysis of databases, we have taken into consideration not only the type of hospital infrastructure, but also the importance that each hospital type holds for the population. In order to establish the importance and therefore the weight of each database, which represents the type of accessibility for a particular hospital type, the spatial analysis equation we have employed the method of the interview on a representative sample of 1425 subjects, made up of residents of the North-West Region with ages ranging from 18-65. After analyzing the answers to the submitted questions, we have obtained a view of the weight of each hospital type as presented in table 8.

Table 6.

Access time values on hospital types and counties

Subcategory	**Code**	**County**																		**GINI index for average**
		CLUJ			**BIHOR**			**BISTRIȚA NĂSĂUD**			**MARAMUREȘ**			**SĂLAJ**			**SATU MARE**			
		Access time (minutes)			**Access time (minutes)**			**Access time (minutes)**			**Access time (minutes)**			**Access time (minutes)**			**Access time (minutes)**			
		Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	
County emergency hospital	1	65.4	366.0	**169.4**	90.3	441.0	**231.7**	0	307.1	**105.7**	0	404.6	**151.8**	0	200.9	**86.6**	0	227.4	**86.8**	0.20
County clinical emergency hospital	11	0	326.7	**107.1**	0	319.9	**119.9**	115.0	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	112.6	455.2	**250.5**	0.20
Clinical emergency hospital	111	106.6	466.2	**299.9**	0	328.4	**120.5**	358.9	699.15	**499.0**	211.5	779.9	**458.7**	100.6	419.8	**229.7**	112.6	492.1	**253.8**	0.23
Military emergency hospital	12	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Clinical emergency children's hospital	1112	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Cardio-vascular emergency hospital	1111	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Clinical hospital	*112*	106.6	466.2	**299.9**	0	328.4	**120.5**	358.9	699.15	**499.0**	211.5	779.9	**458.7**	100.6	419.8	**229.7**	112.6	492.1	**253.8**	0.23
Clinical teaching hospital	*1121*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17

Subcategory	Code	County																		GINI index for average
		CLUJ			BIHOR			BISTRIȚA NĂSĂUD			MARAMUREȘ			SĂLAJ			SATU MARE			
		Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			
		Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	
Municipal hospital	*2*	0	298.9	**100.0**	0	226.6	**71.9**	15.11	336.1	**156.0**	0	381.3	**147.2**	33.7	243.6	**132.5**	0	280.2	**103.9**	0.13
Municipal clinical hospital	*211*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
City hospital	*3*	0	275.2	**112.8**	0	321.6	**127.2**	0	246.7	**95.9**	0	264.3	**102.4**	0	160.3	**64.5**	0	246.1	**105.5**	0.10
Chronic diseases hospital	*4*	41.1	368.4	**209.0**	54.5	408.1	**201.4**	204.0	544.2	**346.6**	80.0	624.9	**307.6**	0	264.9	**94.0**	57.5	367.0	**176.7**	0.20
Pneumology hospital	*5*	110.0	492.7	**282.5**	98.0	532.1	**286.1**	123.3	489.7	**301.6**	0	458.4	**160.86**	82.7	310.8	**170.2**	0	227.4	**88.5**	0.20
Tuberculosis prevention clinic	*51*	20.5	489.3	**188.7**	271.9	589.1	**403.7**	0	333.8	**137.3**	63.4	414.6	**222.4**	61.55	359.1	**216.5**	192.8	445.6	**306.8**	0.19
Clinical hospital for pneumolog..	*52*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Psychiatry hospital	*6*	0	309.3	**126.3**	0	375.8	**165.1**	86.3	407.1	**219.3**	0	415.3	**148.4**	47.4	284.1	**159.1**	111.4	374.0	**221.8**	0.11
Recovery hospital	*7*	119.3	677.6	**373.7**	460.29	777.4	**588.9**	52.3	394.9	**231.4**	0	452.2	**211.0**	250.0	547.6	**401.0**	250.6	557.4	**402.8**	0.18

Subcategory	Code	County																		GINI index for average
		CLUJ			BIHOR			BISTRIȚA NĂSĂUD			MARAMUREȘ			SĂLAJ			SATU MARE			
		Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			
		Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	
Clinical recovery hospital	*71*	0	326.7	**107.1**	0	319.9	**119.9**	115.0	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	112.6	455.2	**250.5**	0.20
Private hospital	*8*	65.4	348.0	**169.3**	0	319.9	**119.2**	0	308.1	**105.7**	0	404.6	**151.8**	0	209	**86.6**	0	227.4	**86.8**	0.14
Private center for recovery, treatment and care	*81*	65.4	366.0	**188.2**	90.3	441.0	**234.3**	183.5	523.7	**325.0**	66.1	604.4	**288.6**	0	244.4	**88.2**	51.7	349.0	**168.7**	0.20
Penitentiary hospital	*10*	0	454.2	**155.3**	236.9	554.0	**368.7**	15.11	355.3	**158.5**	56.4	436.0	**222.1**	33.7	324.2	**182.5**	165.0	410.7	**275.7**	0.17
Clinical hospital for Infectious diseases	*151*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Oncology hospital	*17*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Clinical hospital for urology and renal transplant	*30*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17
Hospital for infectious diseases, dermatology, venerology and psychiatry	*152*	110.0	510.2	**284.3**	215.1	589.9	**372.6**	123.3	489.7	**301.6**	0	458.4	**161.3**	82.7	320.7	**193.6**	50.6	313.3	**168.3**	0.17

Subcategory	Code	County																		GINI index for average
		CLUJ			BIHOR			BISTRIȚA NĂSĂUD			MARAMUREȘ			SĂLAJ			SATU MARE			
		Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			Access time (minutes)			
		Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	Min	Max	**Med**	
Hospital for gastro-enterology and hepatology	*31*	0	353.4	**107.3**	136.0	453.2	**284.8**	115.8	455.1	**251.6**	156.4	535.9	**310.2**	53.9	253.8	**158.1**	177.9	455.2	**291.8**	0.17

Table 7.

Scoring of access time on main hospital categories

Category	Interval in minutes	Scoring grade
Emergency hospitals	0-8	1
	8-12	2
	12-15	3
	15-20	4
	20-30	5
	30-60	6
	60-90	7
	>90	8
Non-emergency hospitals	0-10	1
	10-30	2
	30-60	3
	60-120	4
	>120	5

Table 8.

Weight of databases used in the spatial analysis equation

Category	Subcategory	Code	Weight %
Emergency hospitals	County emergency hospital	1	15
	County clinical emergency hospital	11	20
	Clinical emergency hospital	111	25
	Military emergency hospital	12	5
	Clinical emergency children's hospital	1112	25
	Cardio-vascular emergency hospital	1111	10
Non-emergency hospitals	Clinical hospital	112	3
	Clinical teaching hospital	1121	5.5
	Municipal hospital	2	13,5
	Clinical municipal hospital	211	11
	City hospital	3	20
	Chronic diseases hospital	4	1.5
	Pneumology hospital	5	1.5
	Tuberculosis prevention clinic	51	1.5
	Clinical hospital for pneumology	52	1.5

Category	Subcategory	Code	Weight %
	Psychiatry hospital	6	4
	Recovery hospital	7	6
	Clinical recovery hospital	71	6.5
	Private hospital	8	2
	Private centre for recovery, treatment and care	81	1.5
	Penitentiary hospital	10	2
	Clinical hospital for infectious diseases	151	3
	Oncology hospital	17	7
	Clinical hospital for urology and renal transplant	30	4
	Hospital for infectious diseases, dermatology, venerology and psychiatry	152	2
	Hospital for gastro-enterology and hepatology	31	3

Taking into consideration the fact that in the case of the two types of hospital infrastructure the scoring grades have been defined for different time intervals, its is necessary to draw up two separate spatial analysis models the final databases of which to constitute entry elements into a singular model resulting in the territorial view of areas with differing degrees of accessibility (Fig. 4).

The main operation carried out on databases representing access time in minutes is their reclassification depending on the established scoring grades using the function reclassify of the ArcGIS program, thus obtaining the derivate databases (Fig. 5 a-d) that will be integrated in the spatial analysis equations and in the equations identifying access to the two types of hospital infrastructure.

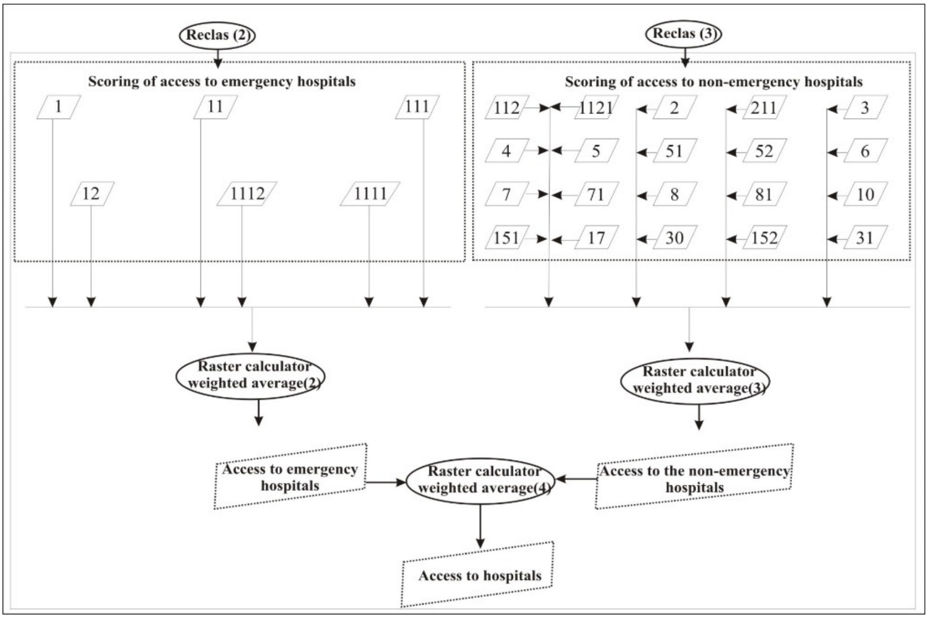

Fig. 4. Territorial accessibility models.

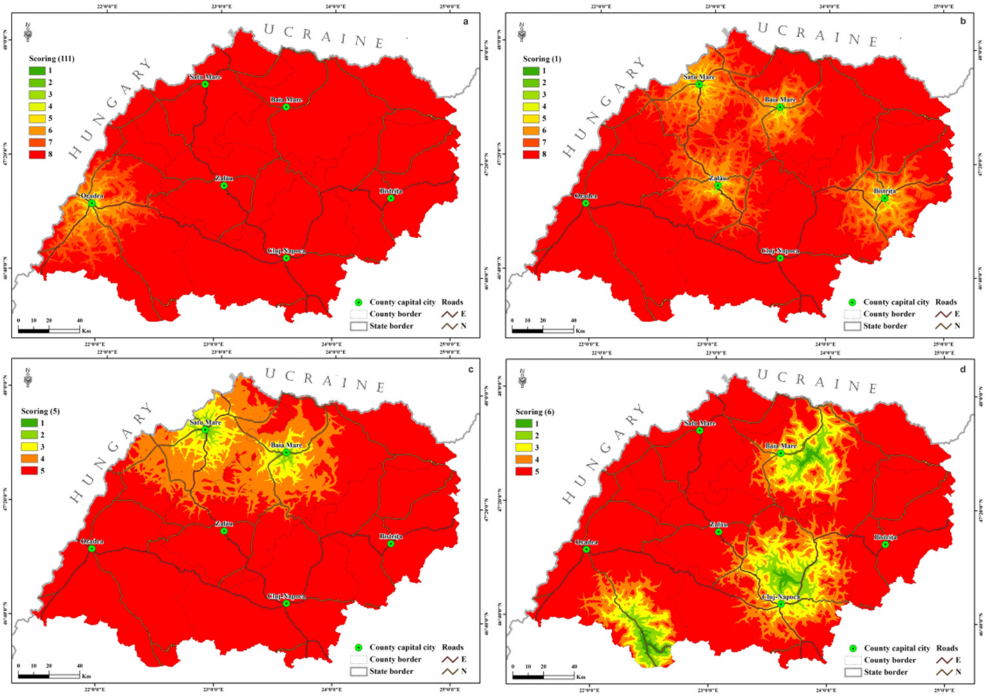

Fig. 5. a. Scoring grades for clinical emergency hospitals; b. Scoring grades for county emergency hospitals; c. Scoring grades for pneumology hospitals; d. Scoring grades for psychiatry hospitals.

The identification of surfaces with various degrees of accessibility (maximal accessibility areas and difficult access areas) has been carried out by using spatial analysis equations on the basis of derived databases resulting from the process of reclassification/scoring as entry elements in these equations.

In order to finalize the two intermediary models and to determine the areas with various accessibility degrees that are specific to the identification model characterizing accessibility to emergency hospitals(Fig. 6 a) and to non-emergency hospitals (Fig.6 b), we have conceived two spatial analysis equations to be implemented into the GIS model as follows:

- ***spatial analysis equation for emergency hospitals:***

*(„Scoring 1111" * 10) + (" Scoring 1112" * 25) + (" Scoring 12" * 5) + (" Scoring 111" * 25) + (" Scoring 11" * 20) + (" Scoring 1 „*15) / 100*

where:

„Scoring 1111" – raster type GRID database representing access time scoring for accessibility to cardio-vascular emergency hospitals

10, 25 ……. –the weight of each database in the final result

- ***spatial analysis equation for non-emergency hospitals:***

*("Scoring 31" * 3) + ("Scoring 81" * 1.5) + ("Scoring 8" * 2) + ("Scoring 71" * 6.5) + ("Scoring 7" * 6) + ("Scoring 6" * 4) + ("Scoring 52" * 1.5) + ("Scoring 51" * 1.5) + ("Scoring 5" * 1.5) + ("Scoring 4" * 1.5) + ("Scoring 30" * 4) + ("Scoring 3" * 20) + ("Scoring 211" * 11) + ("Scoring 2" * 13) + ("Scoring 17" * 7) + ("Scoring 152" * 2) + ("Scoring 151" * 3) + ("Scoring 1121" * 5.5) + ("Scoring 112" * 3) + ("Scoring 10" * 2) / 100*

where:
„Scoring 4" – raster type GRID database representing access time scoring for accessibility to chronic diseases hospitals
3, 1.5 ……. – the weight of each database in the final result
(Emergency deficit: scoring grades).

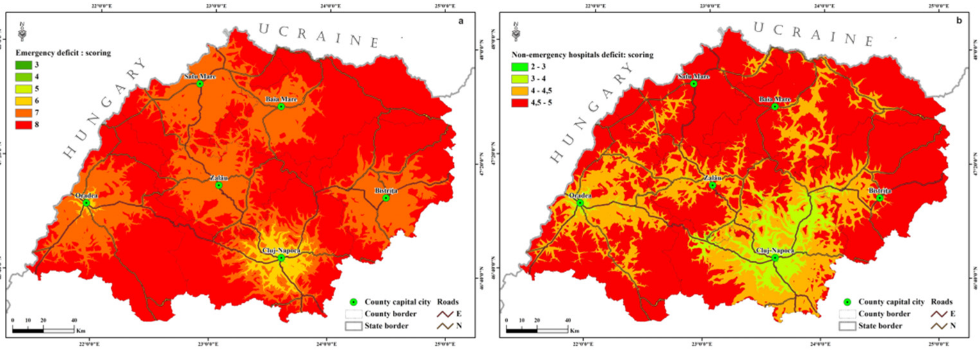

Fig. 6. a. Accessibility to emergency hospitals; b. Accessibility to non-emergency hospitals.

3.2.2. *Identification of deficit areas*

Overlay type spatial analysis carried out by means of the equations for spatial analysis has also been used in determining the deficit in territorial distribution for the entire network of hospitals (emergency and non-emergency). The overlay operation has been conducted by assigning a 60% weight to non-emergency hospitals and the remaining 40% to emergency hospitals, weights that have been obtained from the interpretation of interview results submitted to the questioned subjects, by means of the spatial analysis equation:

*("Hospitals deficit (scoring grades)" * 60) + ("Emergency deficit (scoring grades)" * 40) / 100*

The results are visible in a map of the territorial distribution deficit of the hospitals infrastructure in the North-West Development Region (Fig. 7).

The scoring grades range between 2.8 (maximal accessibility) and 6.5 (minimal accessibility). We notice the existence of apparently paradoxical situations in which some county capital cities display a position of deficit in relation to the hospital network, which can be explained by the small number of hospitals in the non-emergency category in these cities (Baia Mare, Satu Mare, Bistrița, Zalău).

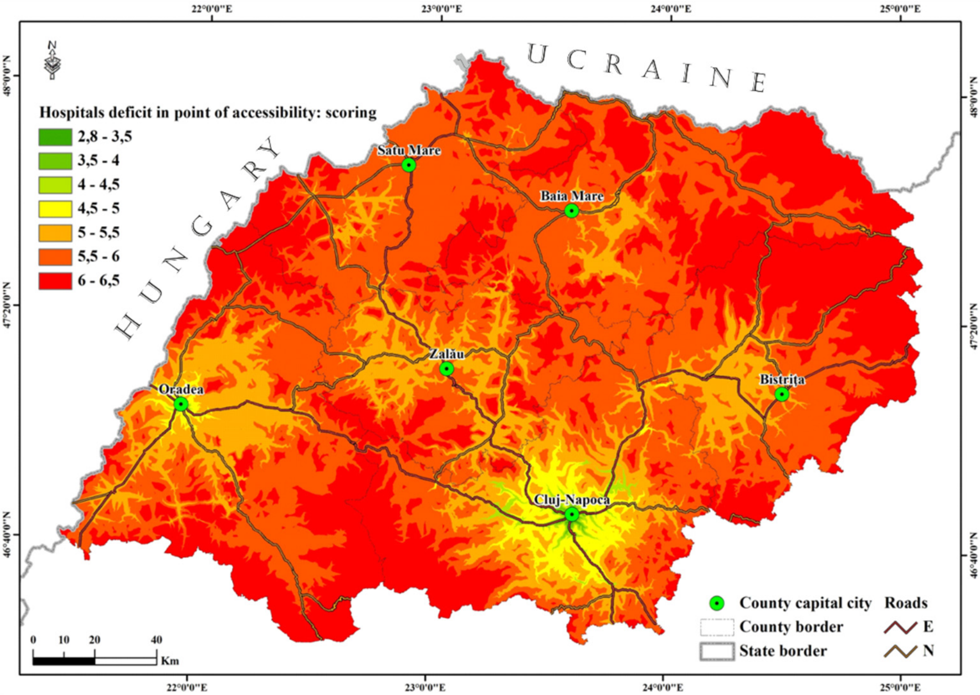

Fig. 7. Areas of deficit in the territorial distribution of the hospital infrastructure in the North-west Development Region.

4. Conclusions

The analysis carried out has revealed a series of practical information that can be useful to the administrative decisional body, such as the areas that display deficit from the point of view of accessibility to hospital units; the maps can be used by the large public by offering information related to the proximity of hospital units. The final databases can be made public by means of WebGIS applications so that people may choose the optimal locations in which to resort to medical care.

The category of emergency hospitals includes the following types: clinical emergency hospitals (Oradea), county clinical emergency hospitals (Cluj-Napoca, Oradea), county emergency hospitals (Baia Mare, Bistrița, Satu Mare, Zalău). Therefore, these are to be found in any county capital city, thus ensuring the appropriate service for areas of immediate proximity. Despite their presence in every county, though, the reference to standardized intervention time reveals the fact that most of the localities are situated in areas where access time exceeds 30 minutes. A particular case is that of the Cardio-vascular emergency hospital and of the Clinical emergency children's hospital that are present only in Cluj-Napoca, therefore their accessibility is very low in relation to the territory of the six counties. To these two, the Military emergency hospital in Cluj-Napoca is added as it displays limited addressability.

For the category of non-emergency hospitals we notice a much better degree of accessibility in what regards access time, both at regional and county level. Thus, the hospitals with the highest accessibility are city hospitals, with an average of accessibility of 101.3 minutes, situated in an interval ranging between 64.5 minutes for the county of Sălaj and 127.2 minutes for the county of Bihor. At the opposite end we find recovery hospitals, characterized by the lowest accessibility level, with access time ranging around 368.1 minutes, situated in an interval ranging between 588.9 minutes for Bihor county and 211.0 minutes for Maramureş county. This fact can be explained by the territorial layout of these hospital types in the North-West Region with one such hospital in Cluj-Napoca, in a favorable position and with a second hospital situated in Borşa (MM), situated at the periphery.

The existing private hospitals are characterized by increased accessibility, with their position in county capital cities, (with the exception of Cluj county) and with their preferential position in relation to main access roads, thus contributing to the overall improvement of the situation.

In what regards the distribution of the areas of deficit in point of accessibility to the hospital network, the areas situated in the vicinity of the cities of Baia Mare, Satu Mare, Bistriţa stand out, a fact that is not generated by the lack of hospitals but rather by the position of the respective cities in relation to the main access roads. Moreover, the areas situated at the Northern and North-East extremities of the region (the Maramureş Depression, the Oaş Depression, the Hills of Bistriţa and the area Oaş-Codru) stand out; this characteristic derives from the scarcity of access roads and their poor quality, which in turn generates a maximum travel speed that is lower than normal. To these the areas is the south of the region are added bordering the counties of Cluj and Bihor, that are mountainous areas with a low density of main transport roads but which displays a network of good communal and service roads characterized by maximal speeds that are very low (30 km/h), with access mainly carried out on foot. The same situation is encountered in other mountainous areas, such as in the Western area of the region, bordering the counties of Bihor and Satu Mare.

The areas with increased favorable conditions are those situated in the immediate vicinity of the cities of Cluj-Napoca, Oradea, and Zalău, positioned on main access roads (E60, E81), which allow high speeds, both inside and outside localities (the maximal speed limit established for all building areas traversed by these two roads is 70 km/h).

Starting from these results, we foresee an opportunity to carry out similar studies in the attempt to identify potential locations for the establishment of new hospital units, possible locations for the establishment of patient transport units and heliports to make up for the difficult road accessibility.

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