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Population distribution by selected road network elements - comparison of centroids, geocoded addresses, built-up areas and total areas on the example of Slovak communes

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Abstract. Two research objectives can be identified in the presented paper. The first one was the development of a point layer, which would abstract from the position of a central point depending on the shape of the territory of the respective spatial unit (commune), and would express the position of a commune as regards the location of the point in the area of the commune built-up area. For such purpose, a geocoding algorithm from Google was used, for which it was possible to prepare a final dot map layer without any terrain layout, as the geocoding algorithm processes only simple text addresses of the relevant spatial units. Such an obtained dot layer was compared with the layer of centroids and the achieved differences were visualised. Another objective was to compare different methods of population distribution interpretation from the selected road network elements at the commune level. Point layers in the form of centroids and geocodes were compared with the spatial population distribution on the basis of the total area and built-up area of a commune.
It is more suitable to use geocodes as the holder of statistical information in comparison with commune centroids, in particular in the areas with marked vertical division of the terrain. In assessing population distribution, the obtained values are much closer to the expression of the identical indicator calculated for the built-up area of a commune that we consider most accurate, which is also documented by the average percentage deviations between particular interpretations of population distribution.

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1. Introduction

Recently, the issue of point presentation for a spatial unit as a centroid or straight away as a geocoded address with the application of various techniques and methods has become a key topic in many scientific papers. Just as the area of research indicates, the relevant issue considerably applies in different spheres of research, and therefore cannot be neglected in science. The papers devoted to geocoding techniques and different methods include those by Duncan et al. (2011), Murray et al. (2011), Karimi et al. (2011) and Zandbergen (2008). A comparison of geocoding techniques on the example of Brazilian towns was shown in the paper by Davis and Alencar (2011) and on a case study of the Yosemite National Park in the USA by Doherty et al. (2011). The papers are mainly related to the area of medicine and epidemiology (McLafferty et al., 2012, Jacquez, 2012), and indicate the importance of the accuracy of spatial unit location with geocoding tools and techniques in research spatial analyses. In the analysis presented in this paper the Google geocoding service was applied. The spatial visualisation and web services of this company were highlighted, for instance in the papers of Pejic et al. (2009), and Zhang and Shi (2007). The positions of centroids and geocoded positions of spatial units bring considerable differences in spatial options and selected analyses, also pointed out in this paper, specifically for population distribution in the context of selected road network elements. To a large extent this topic also appears in spatial analyses in scientific papers; therefore it needs to be dealt with. The general issue of road network was discussed in the papers of e.g. Jenelius (2009), Weiping and Chi (2010), while spatial availability of road network in selected regions was presented by Liu and Yu (2012), and Pantha et al. (2010). Of the papers dealing with population distribution in the context of traffic networks and roads, Chi (2010), Kotavaara et al. (2011), and Morency et al. (2011) can be mentioned. Relations between spatial units and their subsequent analyses are frequent topics of numerous scientific studies. Therefore it is aimed to highlight the resulting differences between the dot representation of spatial units applying its centroid to the analysis, and subsequently a geocoded address of the relevant entity, and the comparison thereof with a standard expression of the spatial phenomenon under review in the form of applied areas (total area, built-up area).

2. Research goals

Part of the standard geographical research is a necessity to visualise statistical data spatially. Usually, this interpretation is in the form of areal (polygonal) or point-defined spatial units. In this paper the authors have tried to approach the major differences in the interpretation of selected data, using various defined spatial units. Centroids, geocoded addresses, built-up areas and total areas of communes become bearers of information. As an example population distribution was used in relation to the selected elements of the road network. The research results are linked to the contribution of Klobučník and Bačík (2012), in which the existence of government websites in the Slovak Republic was analysed. The main impulse for the development of the point layer was the need to display Slovak communes on a website devoted to Slovak self-governments (www.sodbtn.sk/obce/eng). It applies Google Maps services for the display of spatial information (Fig. 1).

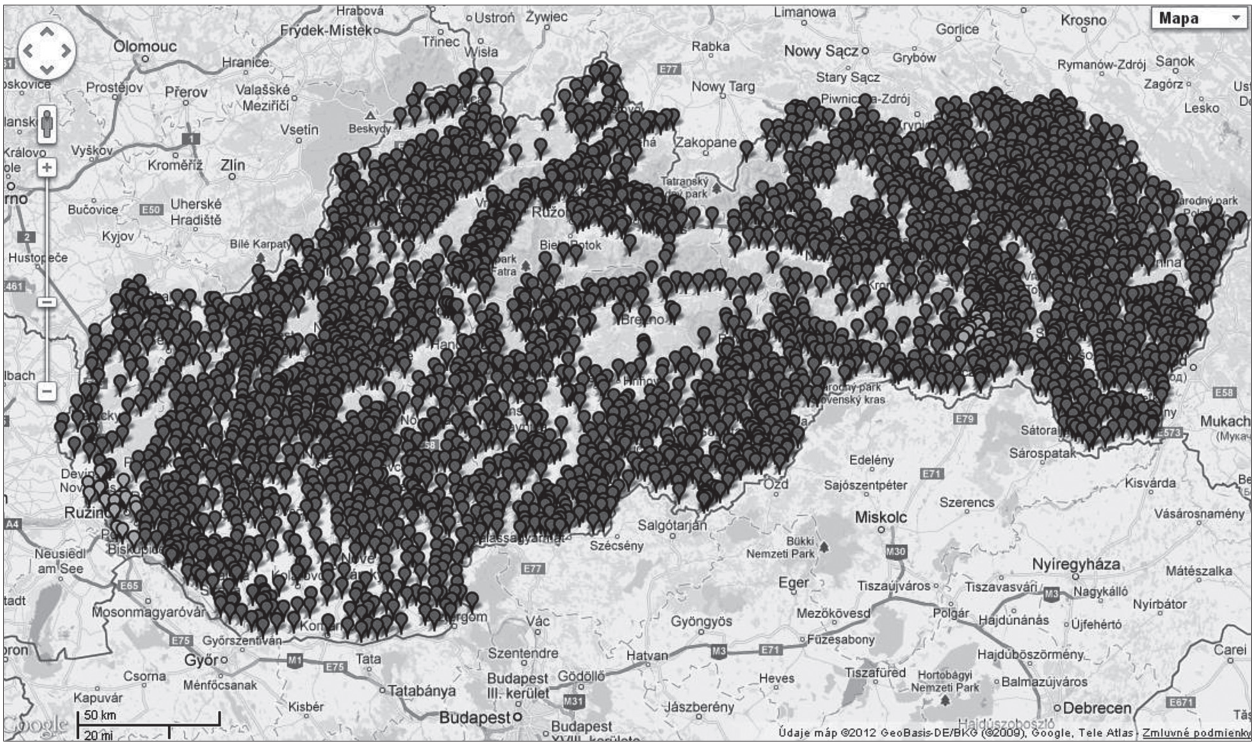

Fig. 1. Point display of Slovak communes using Google Maps

Source: Own processing (http://www.sodbtn.sk/obce/obce_body2.php)

The data obtained in that way were transferred into the form of a map using standard functions in the MapInfo programme. In working with the GIS products, spatial operations based on mutual spatial relation of several map layers are used very frequently. One of the crucial elements of such operations is also the position of the centroid of the relevant spatial unit in relation to other layers. Centroids co-ordinates can be easily obtained and transformed into a relevant map layer.

Centroids of a commune, however, do not represent the real position of a commune within a territorial entity. When viewing the map in detail, a marked shift of centroids from the real position of urban areas is observed, predominantly in mountainous regions (Fig. 2).

The aim was to highlight statistical differences resulting from the spatial analysis applying centroids as well as point location of a commune obtained by geocoding. It will present the position of a commune in space in reality. As a specific example, population distribution in defined distance zones from the selected elements of road network (highways, first class and second class roads) has been displayed. The results are compared on the map, as well as in tables and graphs. In a more detailed scale the results are markedly affected by the already mentioned nature of relief, and the resulting distance of a centroid from the position of a commune obtained from geocoding. In those terms the Slovak Republic is a relevant research area, as some of the selected areas present groups of communes situated in flat regions (Nitra, Zlaté Moravce), while the others in mountainous regions (Ružomberok, Liptovský Mikuláš) (Fig. 3).

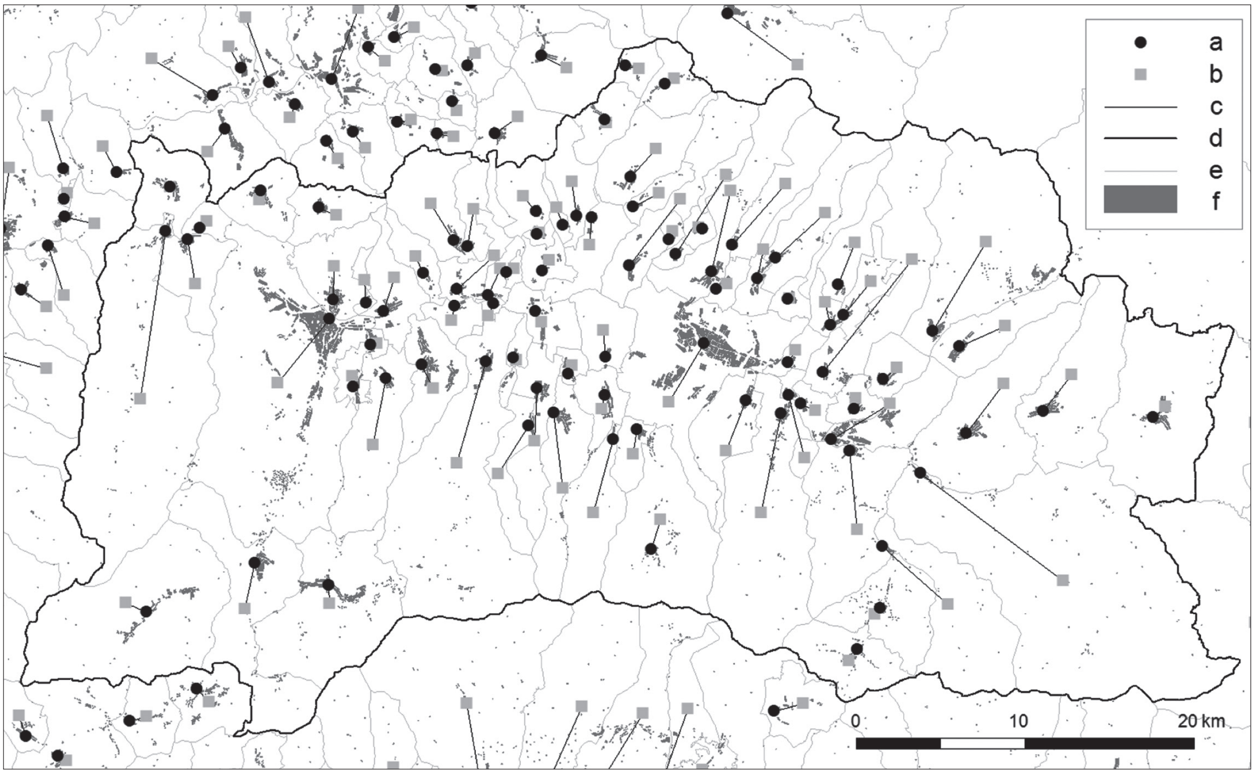

Fig. 2. Comparison of a centroid position and a commune position obtained from geocoding on the example of the Liptov historical region

Explanation: a – commune centre (geocoded address); b – commune centre (centroid); c – difference between a centroid and geocoded address; d – border of the Liptov region; e – borders of communes; f – built-up areas

Source: Own processing

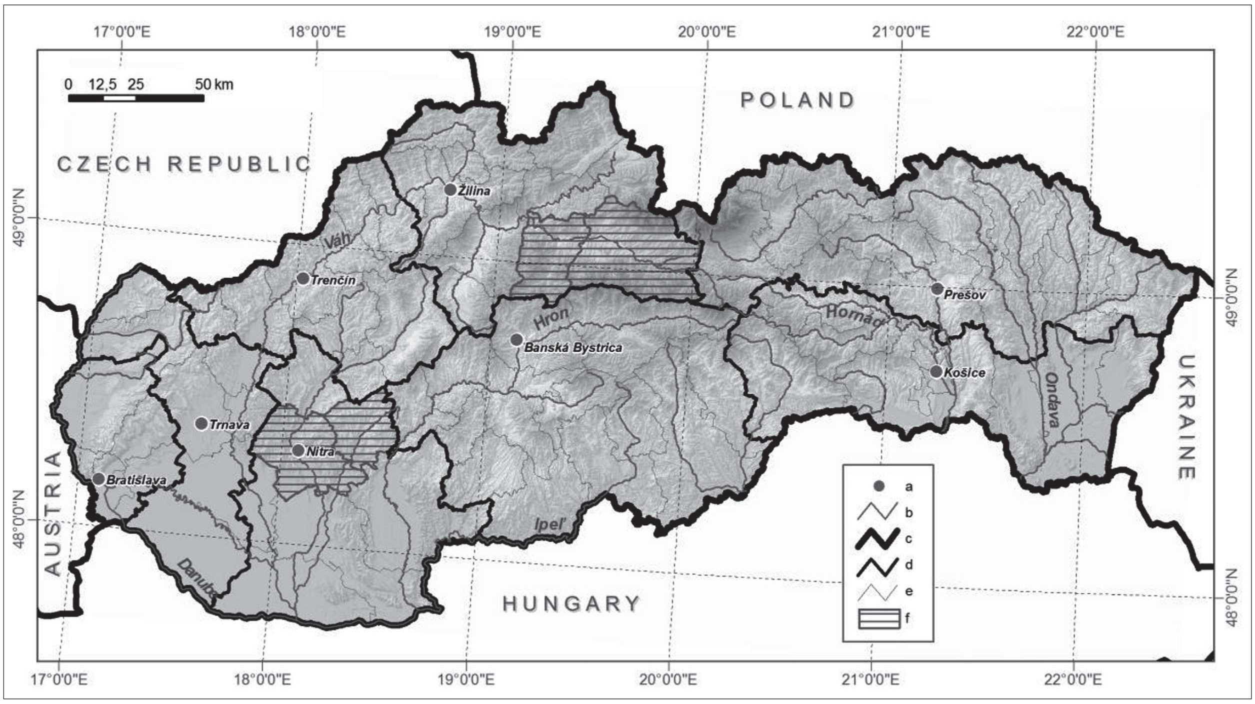

Fig. 3. Representation of a relevant territory with selected geographical elements

Explanation: a – regional centre; b – major river; c – state border; d – regional border; e – district border; f – case study area

Source: Own processing

Representation of population distribution in the form of dots is a pure approximation of the real condition. That is why it was necessary to compare the obtained dot results with an area expression of this indicator in the form of the total area and built-up area of communes (layout 2). Here the total population of particular communes was calculated *pro rata* for a part of area situated in particular zones. The data calculated per built-up area can be considered as the most accurate population distribution. However, even here it is not possible to eliminate several facts affecting real results, such as a number of storeys in buildings, presence of extensive industrial zones, as well as zones with functions other than housing, etc. With respect to the scale of solving the issue, such an expression can be considered sufficient. It is also deemed necessary to point out the work with communes as the least statistical units. Information from official censuses is distributed right at this level. Also smaller, basic units of settlement (BUS) exist, for which data is processed; however, the processing is long-term in our conditions, and the data is distributed with long lapses of time after official census (the data from the 2011 census is still not available). However, their application is not suitable for the authors' needs, as the arrangement of BUS is very heterogeneous; particular BUS units are mainly presented in urban settlements. From the spatial point of view, their arrangement is also very uneven, and in many cases one commune presents one BUS, and vice versa, there are areas the division of which is rather significant (Fig. 4).

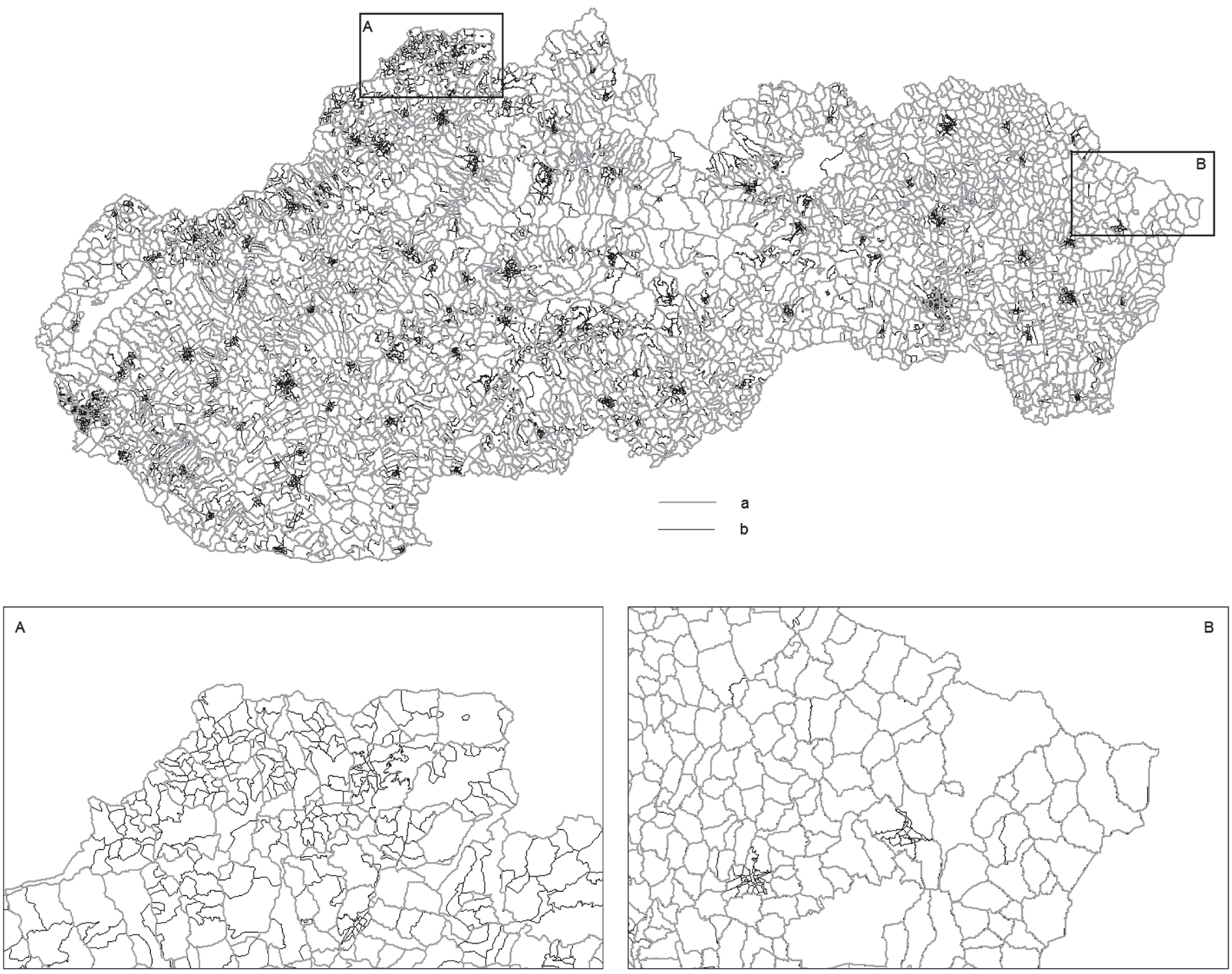

Fig. 4. Comparison of the arrangement of BUS units and communes in the Slovak Republic

Explanation: a – commune border; b – ZSJ (basic residential unit) border; A – viewport of the Kysuce region; B – viewport of the eastern part of the Prešov region

Source: Own processing, based on the basic residential units map layer

3. Methods

At the primary stage of the project it was necessary to develop a point layer for communes, which represents the real position of a commune (built-up area) within the territorial entity with maximum accuracy. The first point layer (a layer of centroids) was developed in a standard manner by calculating the coordinates of the centroid and the relevant commune using the CentroidX, CentoridY function. These coordinates were subsequently saved in a table, from which particular dots (centroids) were created using the "Create Points..."in the environment of the MapInfo programme. The basis for the development of dots for geocoded addresses was the application of the geocoding service from Google. As the address identification, three-stage identification of a commune was applied in the form "commune name, district name, country name". Such identification eliminates identical location of communes with identical names. The results of geocoding in the form of geographical co-ordinates were stored in a server in the MySQL database system. They were then exported, and a point layer was developed in the WGS84 co-ordinate system in a standard manner in the environment of MapInfo Professional. Conversion into the national system S-JTSK was performed in the ArcGIS programme (Fig. 5).

←T→	id	obec	adresa	lat	lng
	841	Liptovský Mikuláš	Liptovský Mikuláš, Liptovský Mikuláš, Slovakia		
	875	Liptovský Hrádok	Liptovský Hrádok, Liptovský Mikuláš, Slovakia		
	876	Liptovský Ján	Liptovský Ján, Liptovský Mikuláš, Slovakia		
	877	Liptovský Michal	Liptovský Michal, Ružomberok, Slovakia		
	878	Liptovský Ondrej	Liptovský Ondrej, Liptovský Mikuláš, Slovakia		
	879	Liptovský Trnovec	Liptovský Trnovec, Liptovský Mikuláš, Slovakia		
	2848	Liptovský Peter	Liptovský Peter, Liptovský Mikuláš, Slovakia		

a

←T→	id	obec	adresa	lat	lng
	841	Liptovský Mikuláš	Liptovský Mikuláš, Liptovský Mikuláš, Slovakia	49.08298111	19.61223412
	875	Liptovský Hrádok	Liptovský Hrádok, Liptovský Mikuláš, Slovakia	49.03651047	19.72021484
	876	Liptovský Ján	Liptovský Ján, Liptovský Mikuláš, Slovakia	49.04816055	19.67789650
	877	Liptovský Michal	Liptovský Michal, Ružomberok, Slovakia	49.09620285	19.43972588
	878	Liptovský Ondrej	Liptovský Ondrej, Liptovský Mikuláš, Slovakia	49.09725952	19.71311188
	879	Liptovský Trnovec	Liptovský Trnovec, Liptovský Mikuláš, Slovakia	49.12126923	19.54717255
	2848	Liptovský Peter	Liptovský Peter, Liptovský Mikuláš, Slovakia	49.05344391	19.73727989

b

Fig. 5. Database table before and after the geocoding process using the geocoding service

a - Before the geocoding process - empty coordinates (latitude and longitude)
b - After the geocoding process - obtained coordinates (latitude and longitude)

Source: Own processing using the MySQL database system

The benefit of the geocoding process is the possibility to develop such a layer without a base map containing the borders of communes. The whole process is the result of launching scripts (in the PHP language) operating with text strings (address entries). In standard GIS programmes it is possible to edit the position of centroids in several ways (e.g. in the MapInfo programme by editing MID/MIF files or by manual movement of their position using the Reshape tool). Such a process is not applicable, however, for a high number of statistical units. The geocoding process itself allows a sort of automation in the shift of centroids into the position located in the built-up area of a commune.

The accuracy of dots created in this way was tested by placing this layer into the map window containing a dot layer of centroids and the geocoded addresses of communes (see Fig. 2). The final accuracy of the dot map layer is affected by the address identification of particular communes. The geocoding algorithm as such was tested with a list of 2,061 ATMs of selected banks in the Slovak Republic. There the dependence between the form of entry of the ATM geocoded address, and the real position of ATMs obtained from the databases of relevant banks operating in the Slovak Republic was tested (Fig. 6).

As shown in the figure, the shape of the address entry does not exert any essential effect on the final accuracy. An exception is the last map where identification gaps were inserted into the address, which resulted in the higher inaccuracy of selected entries. However, as regards the total number, the changes are rather insignificant. For the needs of the analyses at the level of communes, the accuracy stated above would be sufficient (location of dots in a built-up area), so the geocoding algorithm from Google satisfied the requirements regarding the dot location of communes, whereas the accuracy results were verified in a similar process of placing relevant map layers into one map window. To demonstrate differences between the layer of centroids and geocoded position of a commune, the Spider Graph tool was applied; there the interconnection of both layers was performed on the basis of the commune code as a unique identifier. When developing distance zones from the selected road network elements, the Multiple Ring Buffer tool was used. The roads map layer not used as part of the final map was not modified; it was left in the original form in which it was provided from the Office for Geodesy, Cartography and Cadastre of the Slovak Republic. It contains official identification of roads of the relevant category, and therefore no additional modifications were required. In evaluating population distribution on the basis of built-up areas or the total area of a commune, particular areas were cut using the tool "Cookie cutter", which is a free tool for cutting layers in the MapInfo programme. Then the total population was calculated per areas situated in particular distance zones by their share of the total (or built-up) area of a commune.

An important part of the contribution is visualisation of the research results in the form of two mapping layouts (1). A visual appearance of the entire map composition was created in the environment of the MapInfo Professional. The application of a single programme was one of the key targets of the project. By developing the whole solution in this programme, the authors aimed to point out its comprehensiveness and extensive functionality, without the need to use specific graphic editing programmes. The ArcGIS programme from ESRI was only applied to convert between coordinate systems. With respect to the volume of the processed data and two basic objectives of the paper, two maps of the A0 format were selected. A very important role plays the position of centroids and geocoded communes as such; however, due to a high number of points (total 5,854) they were not included in particular maps (layout 1). Their display would result in the illegibility of the phenomenon under review. In the layout, however, three slots displaying these points were selected to demonstrate the reality of specified differences. Urban areas of particular communes were also displayed on the main map to simplify the comparison of centroids and developed point layer just with respect to the built-up area. Differences between the positions of two points in the relevant commune are displayed through lines (created using the already mentioned function SpiderGraph). Differences between communes were also demonstrated in the form of a thematic map, where the size of sign expresses the distance in km. This map was included in a set with respect to the team discussions regarding the simplicity of visual identification of differences. The inclusion of a map displaying communes with a difference larger than 1.6 km and their coverage of mountainous regions, results from the fact that the area of a commune and its position in relation to geomorphological units significantly affects the accuracy of the following analyses (it is only 20% of all communes, but their area makes up almost 40% of the total area of the Slovak Rep.). The next part of the map output shows distance zones from the selected road network elements. The road network itself was not displayed on the maps; it was only used for the development of relevant zones. Again, part of it is also enclosed slots documenting the position of the relevant pairs of points. The inclusion of final

Fig. 6. Accuracy of geocoding process based on the example of ATMs in the Slovak Republic

Explanation: distance a – 0 km; b – 0-0.01 km; c – 0.01-0.02 km; d – 0.02-0.05 km; e – 0.05-0.10 km; f – 0.10-1.00 km; g – 1.00 km and over; A – commune border; B (I) – difference between ATM (official position and geocoded position (address in the form: Banská Bystrica, Na troskách 25); C (II) – difference between ATM (official position and geocoded position (address in the form: Na troskách 25, Banská Bystrica); D (III) – difference between ATM (official position and geocoded position (address in the form: Na troskách 25__, Banská Bystrica)

Source: Own processing

tabular and graphic output is important due to the documented differences, and this presents an important part of the results to be highlighted in the project. No identical colours are used for the zones on the map and in the graphs; in the case of the map output the authors did not want to violate the single-coloured range used as standard, while in the case of the graphs the authors wanted to stress the benchmark distance of 1 km.

The second map set (layout 2) does not show particular distance zones but the distribution of particular areas (built-up and total) depending on their distance zones. For this reason, the set also includes small map blocks below particular maps. The data is cartographically processed specifically for the two types of areas, whereas particular graphs also illustrate the results of population distribution given as centroids and geocodes. To illustrate the results, the bottom part of the layout shows results for flat areas (Nitra, Zlaté Moravce), as well as for mountainous areas (Ružomberok, Liptovský Mikuláš).

4. Results

Working with spatial territorial units (settlements, districts, regions) is often substituted by a point-based representation of a particular unit. The approximation of a point-based representation enables using some analytical tools that are solely available for dot map layers. Representation in the form of the centroid of a particular spatial unit is the simplest transformation of a polygon into a dot/point. Such conversion is possible in all commonly used GIS products. However, this is where a problem arises regarding the centroid location against real occurrence of a monitored phenomenon (in this case population size of a monitored object). The point-based/dot representation by means of a centroid is largely influenced by the vertical segmentation of a monitored territory. The majority of settlements showing a difference between the centroid location and geocoded address (or official point of an object) larger than 1.6 km are located in mountainous areas (Fig. 7).

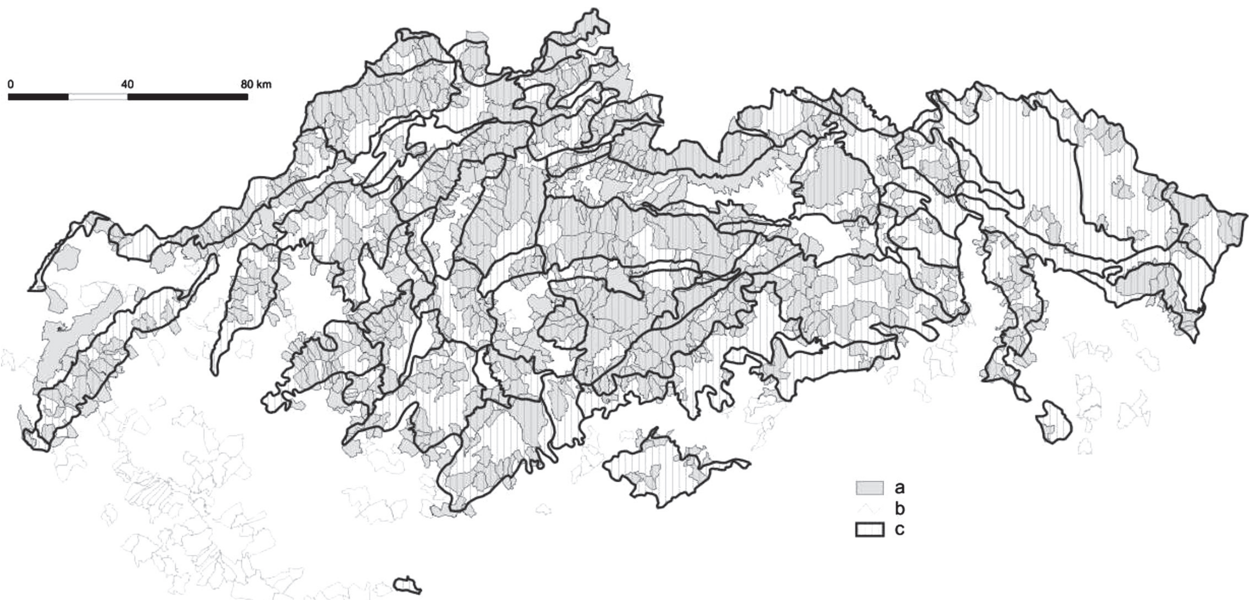

Fig. 7. Position of communes with a difference between centroid and geocoded address larger than 1.6 km

Explanation: a – communes with a difference larger than 1.6 km in mountainous areas (598 communes out of 2,928 (20.4%), total area of 18.277 km^2 (37.2%)); b – communes with a difference larger than 1.6 km; c – border of mountainous area

Source: Own processing

These territories thus cover uninhabited mountainous areas. On the contrary, unlike the location of a centroid, a point-based representation of a settlement with the use of a geocoded address is not influenced by the size and shape of the territory. That is why an area with a significant vertical segmentation was chosen as a model territory as it strongly impacts the results of further analyses. Settlements in mountainous areas differ in shape and size, which is caused by geomorphological profile of such a territory. Population concentrates in the valleys - important traffic corridors, and nearby main centres. These are the facts used to compare population distribution taking into account selected elements of road infrastructure in the selected territory of the Liptov Region (Fig. 8). This is a typical example of a mountainous region with distinctive concentration of population along the main residential axe located along the Váh River. This example was used to show significant differences in the results of population distribution using four main methods of its representation. The value ratios of population living in a particular zone were calculated for individual distance zones; the calculations were based on the total surface area of a settlement, built-up area, centroid location and geocoded address of a particular settlement.

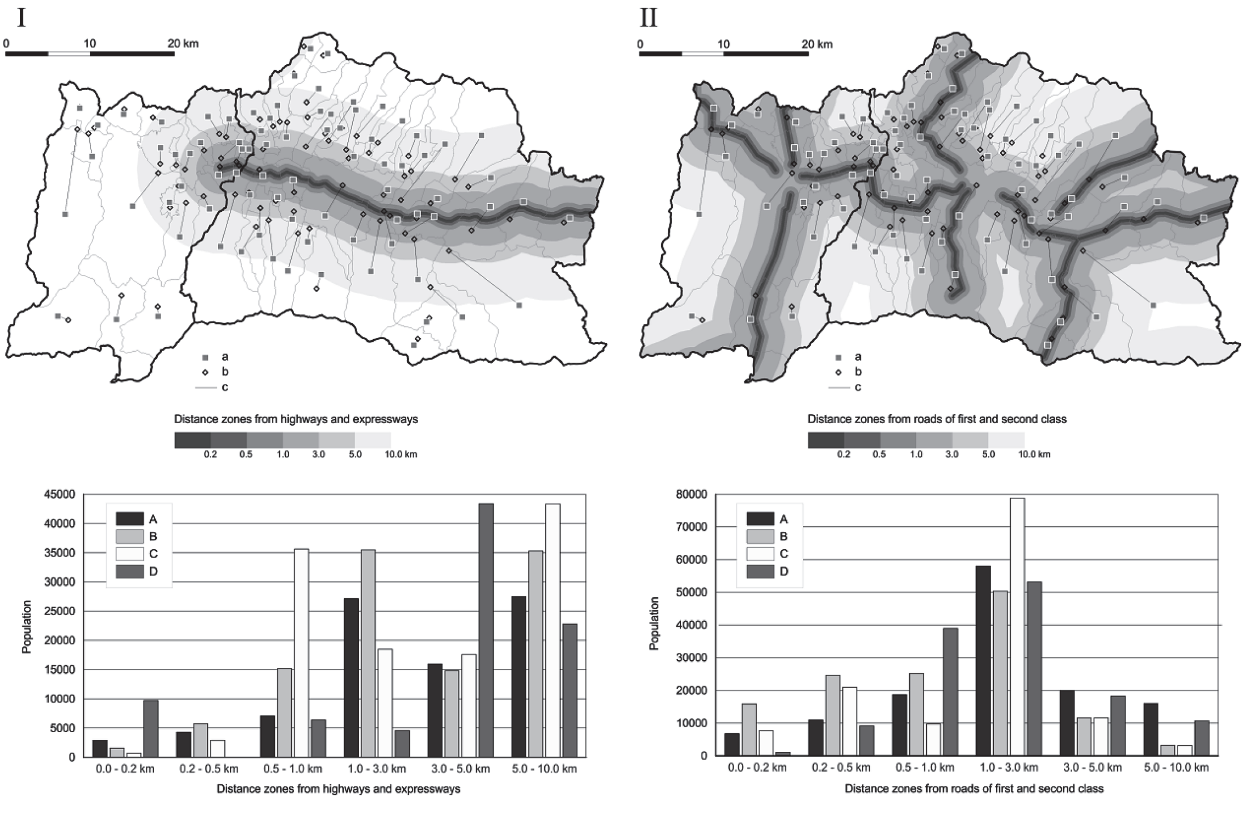

Fig. 8. Comparison of population distribution using four types of interpretation (total area, built-up area, centroids, geocoded addresses)

Explanation: I – expressways and highways; II –first and second class roads; a – commune centre (centroid); b –commune centre (geocoded address); c – difference between the centroid and geocoded address; A – total area; B – built-up area; C – geocodes; D – centroids

Source: Own processing

The data received from the calculated value of the ratios of a built-up area can be considered as the most accurate. At this point, it must be noted again that certain degree of inaccuracy results from the generalisation of such an entry map layer, as well as the existence of large built-up areas of other than residential function (e.g. industrial parks). What is observed, however, is that the differences in the population living in individual distance zones from the selected elements of road infrastructure are relatively significant (taking into account type of interpretation). However, the values of the population defined by a geocoded address (in comparison with the values of the population defined by centroids) are in many cases far closer to the values of built-up areas. Much lower variations in monitored values are observed in the case of lowland regions (territories such as the Nitra and Zlaté Moravce Districts) (2). In these territories much lower differences between the centroids' location and geocoded addresses can be observed as well; this results from the basic vertical segmentation of this territory. Similarly oriented spatial analyses often require using point-based approximation of particular phenomenon and working further with point-based localised values. The use of a centroid is the simplest method of such representation; it is, however, necessary to consider the basic problems of its representation in space relating with the above mentioned facts regarding size, shape and vertical segmentation. The use of the geocoded address records reflecting the existence of built-up and actually inhabited areas of such units is considered more convenient and accurate. Any of the geocoded algorithms available at the company web pages (in this case the Google Geocoding API service) can be used to create such a layer.

5. Conclusions

By comparing the position of the centroid and geocoded position of a commune the authors aimed to point out real differences originating from spatial selections and subsequent analyses based on the selected statistical data. The said example of population distribution by distance zones is one of many examples where this method can be applied in a similar way.

Working with the commune centroid has become standard; however, it is clear from certain studies that the application of such points is at the cost of the accuracy of the results. An important fact is the already mentioned fact regarding the size of a commune and its position in relation to the geomorphological units. In the environment with a marked division of relief, such an application of centroids in different analyses is very distorting, and in some cases even useless.

A crucial moment for the development of a final map is the primary geocoding process. In this case, the geocoding API from Google was applied. However, it is possible to apply other geocoding services available on the Internet. In this way it is possible to develop any point layer that can be subsequently applied while working with the GIS programmes, without the need for the polygon terrain layout of the relevant territorial entity, as the whole geocoding process is based on a text definition of the address specification of the relevant entity. Obtaining a terrain layout for the lowest administrative units of countries is not a simple task. By creating a point layer using the geocoding process, however, it is possible to create thematic maps showing different indicators related to a specific settlement in the form of dots (map diagram, graduated symbol, proportional symbol, etc.). Address entries of communes in the form of *name of_commune, name of_district, name of_country* is sufficient for the needs (in other countries, a similar method can be applied, where the address entry would apply the relevant hierarchic division). The accuracy of the final point layer was verified by comparing the developed map layer of geocodes, and placing it on the layer of the official definition points of the Slovak Republic, which was purchased from the Slovak Institute of Geodesy and Cartography (Fig. 9).

Differences among particular dots (communes) are much smaller than differences among centroids and geocodes, whereas the main benefit, in addition to higher accuracy, is the already mentioned development of geocodes without the use of any terrain layout. With respect to the indicator of population distribution under review, it is clear that it is not a dot localised phenomenon; the interpretation in the form of dots is just a sort of approximation of the real condition. Therefore, in the next stage these results were compared with the total and built-up area of a commune, whereas for particular zones the shares of inhabitants relating to the relevant unit were calculated per the share of area situated in the relevant zone (the main map layout 2). Herewith, the authors aimed to highlight the main differ-

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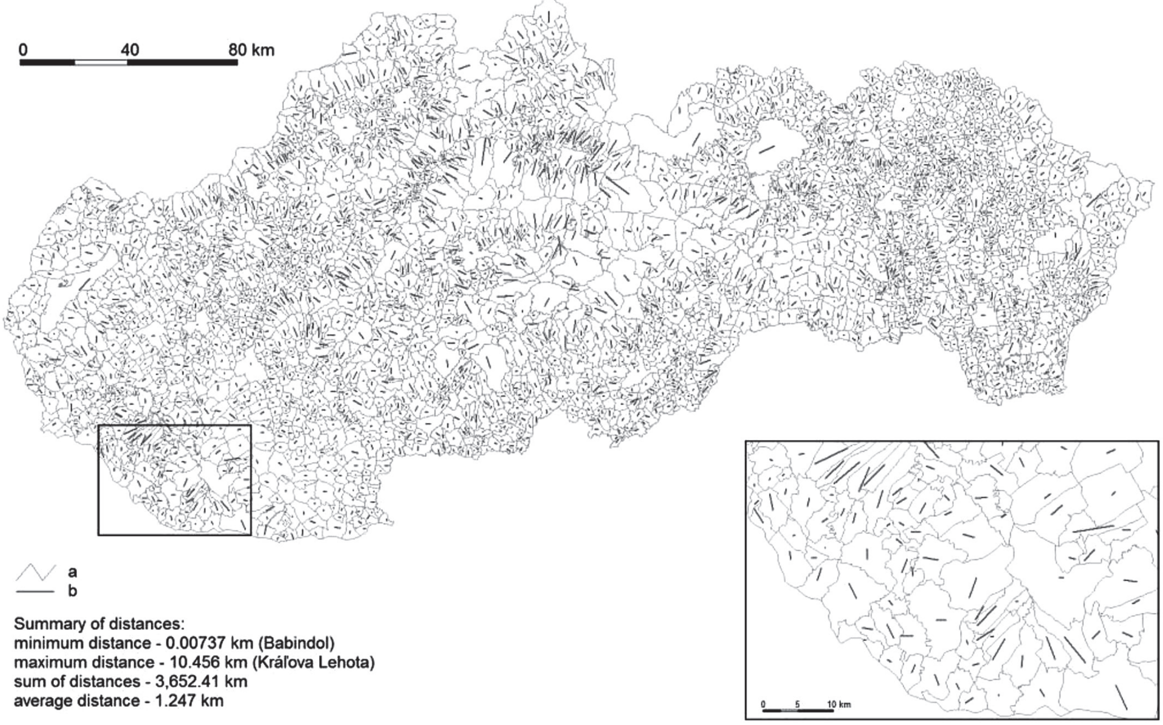

II

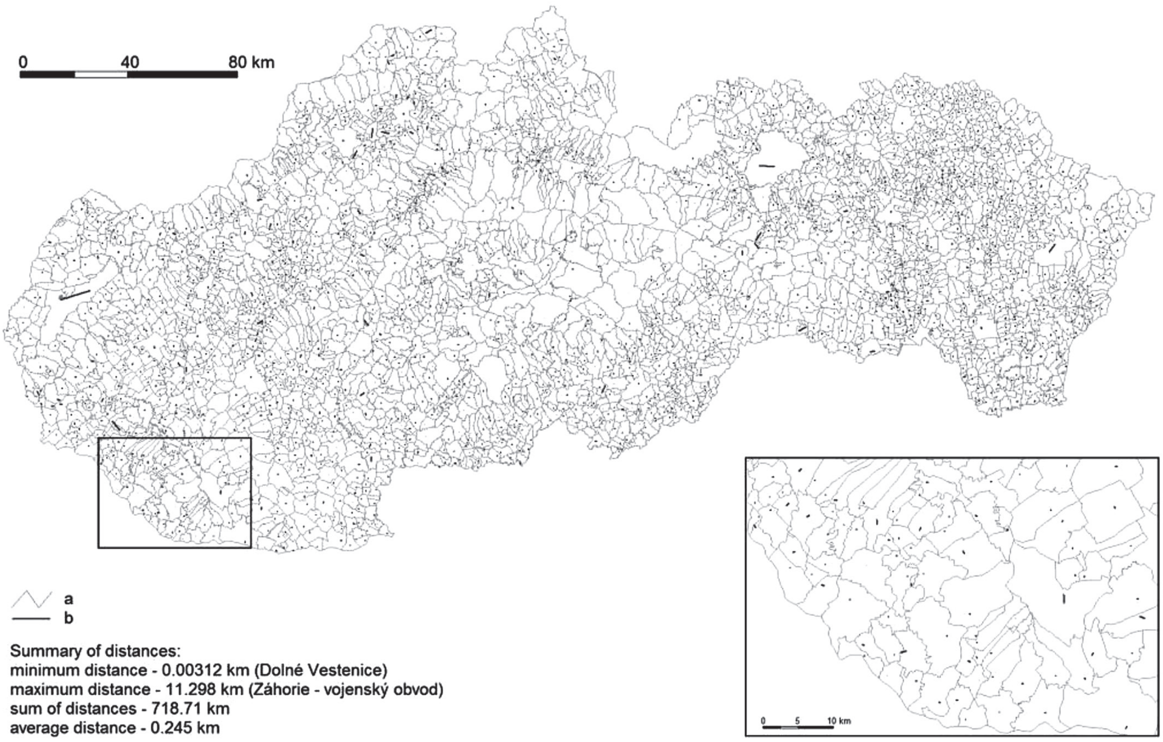

Fig. 9. Comparison of centroids (I) and official definition points (IGC) (II) with geocodes

Explanation: I - Comparison of differences between centroids and geocoded addresses; II - Comparison of differences between official definition points and geocoded addresses; a – commune border; b – difference between definition point and geocoded position

Source: Own processing

ences originating in these four methods of specifying population distribution by distance zones. Land relief can be considered the key factor determining the relation among four such methods of population distribution evaluation. In mountainous regions, the population expressed as geocodes is closes to the values calculated per built-up area. Lower percentage deviations in almost all distance zones (between built-up areas and geocodes) also prove this. In contrast, in plain areas there are very similar results obtained both with centroids and geocodes (affected by the size and shape of the administrative unit), while higher mutual similarity is also shown among the shares of inhabitants calculated per total and built-up areas. Naturally, the dot manifestation of such phenomenon brings a certain degree of inaccuracy; however, with respect to the obtained results it can be said that the application of geocodes is more adequate than of centroids. Similar examples can be found in Slovakia, as well as in other countries, such as Austria and Switzerland – Alpine regions, and Poland – large-area units, etc. However, the main benefit is the option of processing and subsequent visualisation of the data for large areas for which there are no detailed terrain layouts on the level of administrative units.

Acknowledgements

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Notes

(1) Mapping layouts in full resolution are available at: http://www.sodbtn.sk/download/final_layout_bk.pdf

(2) Study area of the regions Nitra and Zlaté Moravce as well as population distribution are displayed on the second page of the map layout

References

Davis, C.A. and Alencar, O.R., 2011: Evaluation of the quality of an online geocoding resource in the context of a large Brazilian city. In: *Transactions in GIS*, Vol. 15, Issue 6, pp. 851-868. DOI: http://dx.doi.org/10.1111/j.1467-9671.2011.01288.x

Doherty, P., Guo, Q., Liu, Y. and Wieczorek, J., 2011: Georeferencing Incidents from Locality Descriptions and its Applications: a Case Study from Yosemite National Park Search and Rescue. In: *Transactions in GIS*, 15(6), pp. 775-793. DOI: http://dx.doi.org/10.1111/j.1467-9671.2011.01290.x

Duncan, D.T., Castro, M.C., Blossom, J.C., Bennett, G.G. and Gortmaker, S.L., 2011: Evaluation of the positional difference between two common geocoding methods. In: *Geospatial Health*, Vol. 5, Issue 2, pp. 265-273.

Chi, G., 2010: The Impacts of Highway Expansion on Population Change: An Integrated Spatial Approach. In: *Rural Sociology*, Vol. 75, Issue 1, pp. 58-89. DOI: http://dx.doi.org/10.1111/j.1549-0831.2009.00003.x

Jacquez, G.M., 2012: A research agenda: Does geocoding positional error matter in health GIS studies? In: *Spatial and Spatio-temporal Epidemiology*, Vol. 3, Issue 1, pp. 7-16. DOI: http://dx.doi.org/10.1016/j.sste.2012.02.002

Jenelius, E., 2009: Network structure and travel patterns: explaining the geographical disparities of road network vulnerability. In: *Journal of Transport Geography*, Vol. 17, Issue 3, pp. 234-244. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2008.06.002

Karimi, H.A., Sharker M.H. and Roongpiboonsopit, D., 2011: Geocoding Recommender: An Algorithm to Recommend Optimal Online Geocoding Services for Applications. In: *Transactions in GIS*, Vol. 15, Issue 6, pp. 869-886. DOI: http://dx.doi.org/10.1111/j.1467-9671.2011.01293.x

Klobučník, M. and Bačík, V., 2013: Spatial autocorrelation of communes websites: A case study of the region Stredné Považie in Slovak Republic. In: Szymańska, D. and Biegańska, J. editors, *Bulletin of Geography. Socio-economic Series*, No. 22, Toruń: Nicolaus Copernicus University Press, pp. 65–80. DOI: http://dx.doi.org/10.2478/bog-2013-0032

Kotavaara, O., Antikainen, H. and Rusanen, J., 2011: Population change and accessibility by road and rail networks: GIS and statistical approach to Finland 1970–2007. In: *Journal of Transport Geography*, Vol. 19, Issue 4, pp. 926-935. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2010.10.013

Liu, Ch. and Yu, R., 2012: Spatial Accessibility of Road Network in Wuhan Metropolitan Area Based on Spatial Syntax. In: *Journal of Geographic Information System*, Issue 4, pp. 128-135. DOI: http://dx.doi.org/10.4236/jgis.2012.42017

Mclafferty, S., Freeman, V.L., Barrett, R.E., Luo, L. and Shockley, A., 2012: Spatial error in geocoding physician location data from the AMA Physician Masterfile: Implications for spatial accessibility analysis. In: *Spatial and Spatio-temporal Epidemiology*, Vol. 3, Issue 1, pp. 31-38.

Morency, C., Paez, A., Roorda, M.J., Mercado, R. and Farber, S., 2011: Distance traveled in three Canadian cities: Spatial analysis from the perspective of vulnerable population segments. In: *Journal of Transport Geography*, Vol. 19, Issue 1, pp. 39-50. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2009.09.013

Murray, A.T., Grubesic, T.H., Wei, R. and Mack, E.A., 2011: A Hybrid Geocoding Methodology for Spatio-Temporal Data. In: *Transactions in GIS*, Vol. 15, Issue 6, pp. 795-809. DOI: http://dx.doi.org/10.1111/j.1467-9671.2011.01289.x

Pantha, B.R., Yatabe, R. and Bhandary N.P., 2010: GIS-based highway maintenance prioritization model: an integrated approach for highway maintenance in Nepal mountains. In: *Journal of Transport Geography*, Vol. 18, Issue 3, pp. 426-433. DOI: http://dx.doi.org/10.1016/j.jtrangeo.2009.06.016

Pejic, A., Pletl, S. and Pejic, B., 2009: An expert system for tourists using Google Maps API, Intelligent Systems and Informatics, 2009. SISY '09. 7th International Symposium on, pp. 317-322. DOI: http://dx.doi.org/10.1109/SISY.2009.5291141

Weiping, H. and Chi, W., 2010: Urban Road Network Accessibility Evaluation Based on GIS Spatial Analysis Techniques. In: *The International Archives of the Photogrammetry*, Remote Sensing and Spatial Information Sciences, Vol. 38, Part II, pp. 114-117.

Zandbergen, P.A., 2008: A comparison of address point, parcel and street geocoding techniques. In: *Computers, Environment and Urban Systems*, Vol. 32, Issue 3, pp. 214-232. DOI: http://dx.doi.org/10.1016/j.compenvurbsys.2007.11.006

Zhang, J.Y and Shi, H., 2007: Geospatial Visualization using Google Maps: A Case Study on Conference Presenters. In: *Computer and Computational Sciences*, 2007. IMSCCS 2007. Second International Multi-Symposiums on; 09/2007, pp. 472-476.

www.sodbtn.sk/obce/eng