

APPLICATION OF GEOMATICS IN URBAN PLANNING USING OPEN-SOURCE GEOSPATIAL DATA AND GIS SOFTWARE

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Abstract: The objective of this study is to show possible applications of geomatics in the field of urban planning. Using QGIS, open-source GIS software, three methods for delineating service area were employed, in order to determine the boundaries of geographic accessibility of Clinical Center Niš. First method applied in this study was buffering method. It was done by creating a buffer zone with the 5km radius around target location. Since buffering method does not account for existing road network, the network distance-based approach was employed and the second method applied was the shortest network distance method. For size of Iso-Area value of 5000m was chosen. Third method applied in this study was speed-based delineation method, for which 5 minutes interval was set. The results obtained show that the network distance-based methods provide higher accuracy, comparing to buffering method, emphasizing their ability to recognize differences in accessibility across the urban environment.

Key words: service area delineation, network distance approach, urban planning, QGIS, GIS analysis

1. INTRODUCTION

Geomatics is a discipline that encompasses the tools and techniques used in traditional fields such as informatics, cartography, geography, geodesy, remote sensing and photogrammetry, as well as in modern technologies such as GNSS (Global Navigation Satellite Systems), GIS (Geographic Information Systems), spatial databases, SDI (spatial data infrastructures) and BIM (building information modeling). [1].

In the context of modern spatial planning, GIS technology is increasingly used in the domain of geospatial analysis. One of the most popular GIS software, QGIS, an open-source software, offers a number of tools for geospatial analysis, including network-based service area analyses. This type of analysis is available through QNEAT, a Python-based QGIS plugin, integrated in the QGIS3 processing framework [2]. Using QNEAT, it is possible to perform simple analysis, like shortest path, but also to solve more complex tasks like Isochrone polygons as service area and OD-Matrix (Origin-Destination-Matrix) computation [3]. Such tools are very useful for purposes of evaluation of public service accessibility and availability, since, according to [4], a good access to public services can decrease the inequality by around 20 % in OECD countries. This percentage could be higher in other less developed countries like Serbia, especially in city areas [2]. Taking into account that Clinical Center Niš is the most important health center in city of Niš, this study aims to bring an overview of the urban accessibility to this health facility, by applying QGIS tools.

There are several approaches to service area analysis, and one of the most commonly used is buffering method, which is based on the concept of Euclidean distance metrics, that is, it assumes ‘as the-crow-flies’ movement. The main disadvantage of this method is that it determines the straight-line distance between two points, neglecting the existing road network in urban areas. Therefore, the common view is that Euclidean distance is unsuitable for solving any spatial query in road networks as road network distance can be significantly different to Euclidean distance [5]. In order to overcome the disadvantages of the buffering method, network distance-based methods were adopted. There are two approaches to using network distance: the shortest network distance and the speed-based delineation method. The shortest network distance method is implemented directly in GIS software [6], using a shortest path algorithm, and depicting the actual travel trajectory [7]. The speed-based delineation method, involving travel time calculations, is also implemented in GIS software [6]. For this method, additional data are required, such as estimated speed and length of road segments [7].

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2. MATERIALS AND METHODS

The main approach of this study is to rely on open-source software and geospatial data [2]. Thus, QGIS software and OpenStreetMap (OSM) data were used. The process consisted of two basic steps which are described in the following subsections.

2.1. Data Collection and Preprocessing

For the purposes of this study, the urban area of the city of Niš, Serbia, was selected. Data for the boundaries of the urban area were downloaded from the website data.gov.rs [8], in .geojson format. Data for road network and spatial layout of hospitals for the territory of city of Niš were downloaded from OSM, the free wiki world map. Since the downloaded data from OSM covered larger area then selected urban area of city of Niš, these data were cut out to the defined boundary of urban area using Clip tool in QGIS. Hospitals are shown as polygons on OSM, therefore it was necessary to „replace“ them with centroids, that is, to derive the centroids of the hospital polygon features. For the purposes of speed-based delineation analysis, the attribute table of the layer Roads was supplemented with a new field, named “speed”, which contains defined speed values for different road categories. The all downloaded data were presented in WGS84 coordinate system. Since for the purposes of network analysis, GIS data must be in a projected coordinate system, EPSG:3909 - MGI 1901 / Balkans zone 7 coordinate system was selected for this study.

2.2. Service area analysis

First method applied for service area analysis in this study, buffering method, was done by creating a buffer zone in QGIS, with the 5km radius around Clinical Center Niš, which was used as the target location. After process completed, a temporary layer called Buffered was added into Layers panel in QGIS. Result is shown in Figure 1.

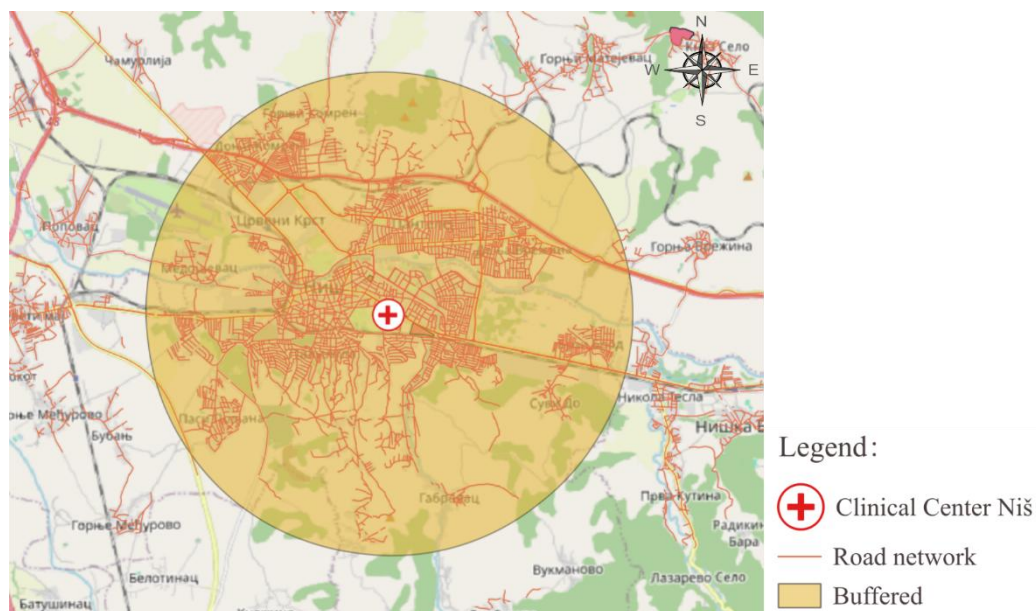


Figure 1 – 5-km buffer around Clinical Center Niš

The second method applied to delineate service area was the shortest network distance method, for which Iso-Area as Polygons (from Layer) function of QNEAT3 plugin was used. For size of Iso-Area (distance or time value), value of 5000m was chosen. For path type to calculate, Shortest Path option was selected. Road network data was taken into account, by choosing layer Roads for vector layer representing network. When the process completed, two temporary layers were created: Output Polygon and Output Interpolation. The Output Interpolation layer is a raster layer, created using triangular irregular network (TIN). The Output Polygon layer is a vector layer, that is, a polygon

feature, showing the 5-km area of service availability for the Clinical Center Niš. Result of this method is shown in Figure 2.

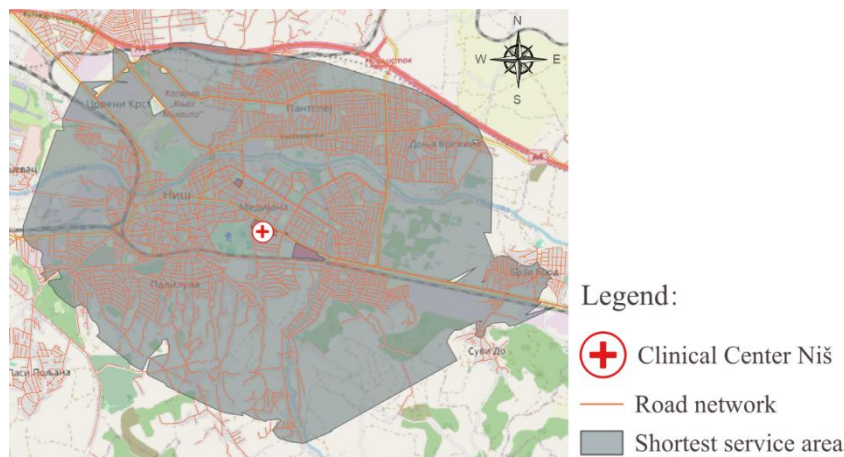


Figure 2 – 5-km shortest service area of Clinical Center Niš

The third method applied in this study was speed-based delineation method. Iso-Area as Polygons (from Layer) function of QNEAT3 plugin was used again for this approach. For size of Iso-Area (distance or time value), value of 300 was chosen. This way 5 minutes interval was set. For path type to calculate, Fastest Path (time optimization) option was selected. When the operation completed, similar to the previous method, two temporary layers were created. One of the output layer is called Output Polygon, which shows the 5-minutes drive-time service area of Clinical Center Niš, as shown in Figure 3.

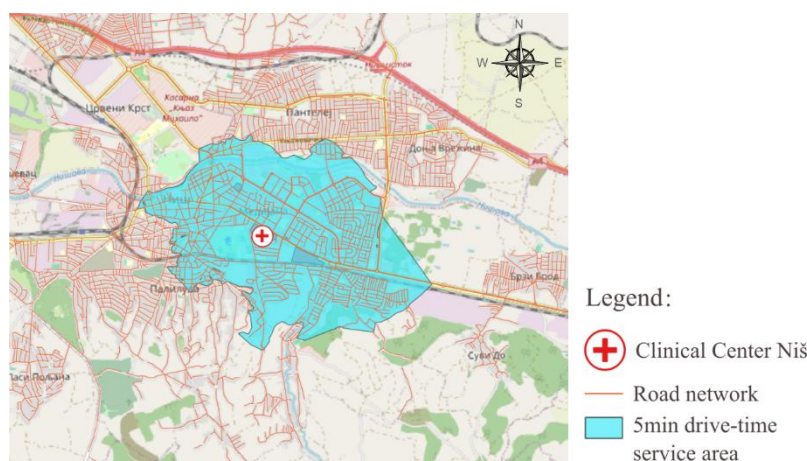


Figure 3 – 5-minutes drive-time service area of Clinical Center Niš

3. RESULTS AND DISCUSSION

The buffering method generated uniform service area with a size of 84.70 km². However, when applying buffer analysis, the one has to keep in mind that the assumption about buffer area was made, that every individual has equal accessibility to the target location, neglecting factors like road network density, possible existence of physical barriers, or traffic conditions. Thus, it gives simplified and overestimated representation of service area.

On the other hand, the shortest network distance method gave a more realistic service area. Much smaller service area of 35.64 km² was derived, due to the network constraints. Results obtained from the interpolation raster were 351.88m for minimum and 5195.92m for maximum distance, with the mean value of 3472.48m and the standard deviation of 1026.68m. The average travel time was calculated at 6 minutes.

The speed-based delineation method gave following results: the service area size was the smallest, comparing to other two, at 9.33 km², since the travel time was limited to 5min. Accessibility values obtained from the interpolation raster ranged from 98.90m to 305.94m, with a mean of 244.77m and a standard deviation of 40.04m. Summary of statistical metrics for all three methods is given in Table 1.

Table 1 – Summary of Statistical Metrics

Method	Service Area Size (km ²)	Average Travel Time (min)	Accessibility (Mean ± SD)
Buffering Method	84.70	-	-
Shortest Network Distance	35.64	6	3472.48 ± 1026.68
Speed-Based Delineation	9.33	5	244.77 ± 40.04

In order to illustrate results from Table 1, a comparison of service areas, obtained from three different methods is shown in Figure 4.

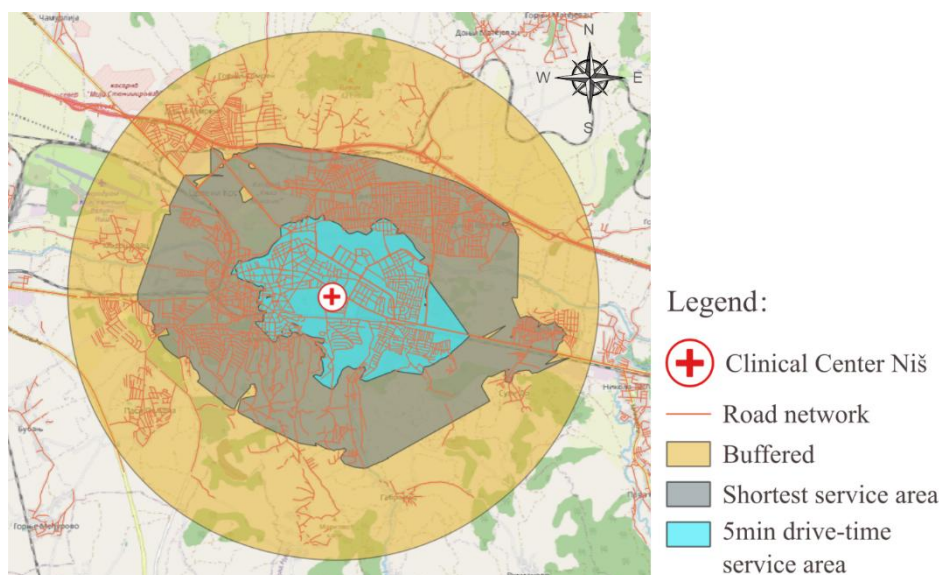


Figure 4 – Service Area Comparison

As it can be seen in Figure 5, there are large inequalities in service accessibility among different parts of the urban area for both shortest network distance and speed-based delineation methods.

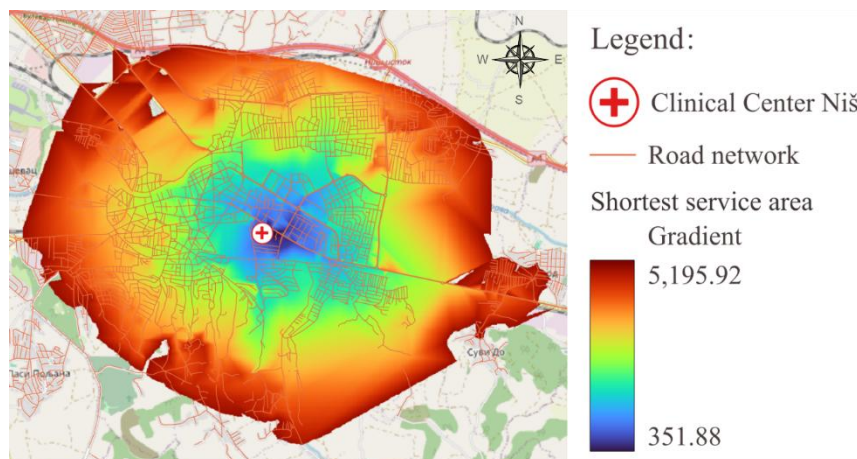


Figure 5(a) – Shortest Network Distance

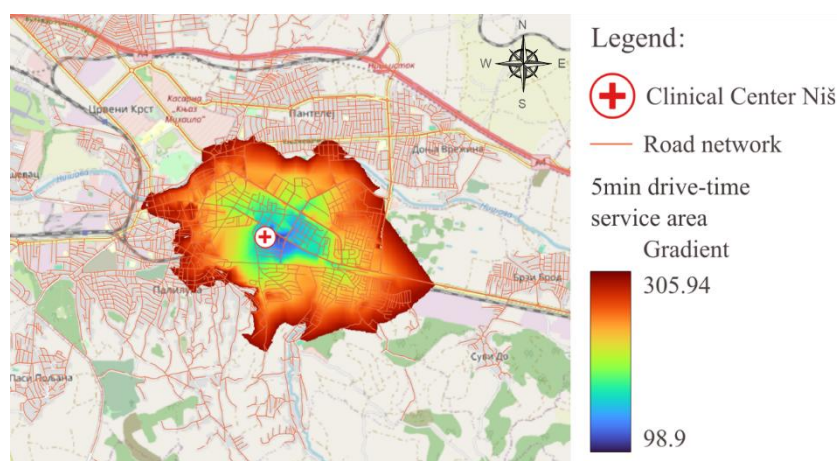


Figure 5(b) – Speed-Based Delineation

Figure 5 – Accessibility Gradients

4. CONCLUSION

This study presented possible applications of geomatics in the field of urban planning. Three different methods for delineating service area were applied in order to determine the boundaries of geographic accessibility of Clinical Center Niš. Open-source GIS software, QGIS, and geospatial data, downloaded from OSM, were used. OSM data supplied with information about road network and spatial layout of hospitals for the territory of city of Niš. Iso-areas were generated using QNEAT plugin in QGIS3, and determined service area coverage for travelling distance of 5 km, and travelling time of 5 minutes from target location.

The results showed that the buffering method is very simple, but lacks consideration of real world phenomena such as network connectivity of roads and movement dynamics, and therefore tends to overestimate the service coverage. Comparing to other two methods, it obtained the largest service area of 84.70 km². On the other hand, the network based methods gave more accurate and detailed results. Applying the shortest network distance method, physical arrangement of the road network was taken into account, which resulted in accessibility variations, with smaller service area of 35.64 km². The speed-based delineation method refined these results by taking into account the speed of movement. It resulted with the smallest service area determined, at 9.33 km², giving the most realistic representation of service area.

Future studies could focus on integrating additional data layers, such as layers containing information about population and public transportation, in order to improve the precision of accessibility analyses.

5. REFERENCES

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