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EXAMINATION OF AMBULANCE ARRIVAL TIMES BY GEOINFORMATICS TOOLS – EXAMPLE OF BORSOD-ABAÚJ-ZEMPLÉN COUNTY (HUNGARY)

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Abstract: An essential part of the health system is the ambulance service, whose main task is to provide patients with high quality care. In the spirit of the above, the aim of the study is to explore the spatial characteristics of the ambulance service in a Hungarian territorial unit, Borsod-Abaúj-Zemplén county. The main findings of the study are:
- The geographical location of ambulance stations in the county is strongly influenced by geography and demographic characteristics.
- The designation of the coverage areas of ambulance station is fundamentally consistent with the access time to the respective ambulance stations.
- The accessibility of each settlement from the ambulance station and the time needed to travel the ambulance station - location - hospital route differ for the speed allowed by the Highway Code and for the speed of 60 km/h

Key words: ambulance stations, ambulances, Borsod-Abaúj-Zemplén county, access time

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INTRODUCTION

Due to the deteriorating overall health of Hungarian society and the ageing population of the country, safe access to healthcare has become increasingly important in recent years. At the same time, patients' chances of survival significantly depend on how fast the ambulance services can get them to healthcare facilities providing the necessary care.

There is a substantial body of literature available on this topic both from Hungary and internationally (Beke, 2019; Barry et al., 2018; Égi et al., 2015; Ishikawa, 2019; Kolivand, 2020; Knyazkov et al., 2015; Yasunaga et al., 2011), at various territorial levels, with slightly differing methodologies and demographic data.

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Kemkers et al. (2010) have studied the spatial characteristics of ambulance services in Hungary. Their analysis is based on a seemingly feasible plan proposing the creation of 23 new ambulance stations, taking into account questions of cost-effectiveness and rationality. Bugya et al. (2015) have created a model that can be used to identify weaknesses and to address ad hoc situations more successfully, thus also contributing to long-term planning.

Murad (2018) presented a potential application of GIS in connection with research in the field of health geography. Using Network Analyst in ArcGIS, he investigated the accessibility of healthcare centres in the city of Jeddah in Saudi Arabia. The results showed that there are several zones in the central and northern areas of Jeddah that are considered underserved in terms of healthcare services, and therefore it would be advisable to develop health services in these parts of the city.

Estember et al. (2019) studied the current performance of public and private ambulance services in Quezon City in the Philippines. Their analysis is highly complex, with several elements taken into account in their calculations, of which location, traffic conditions and time of day were found to be prominent factors. Furthermore, the speed of the ambulances, the weather, and the readiness of the ambulances also had a significant impact on how fast patients could be reached, as did also how fast the ambulance services could react to various force majeure situations.

Wajid et al. (2020) researched the coverage provided by the ambulance network in South Delhi. For the analysis, they used data on fatal accidents in the period 2014-2016, which they grouped according to different criteria. A total of 100 locations were examined to optimally locate the current 29 stations in the area, providing the most ideal coverage possible. Their results showed that with a suitable design, as few as 11 ambulance stations could provide 100% coverage.

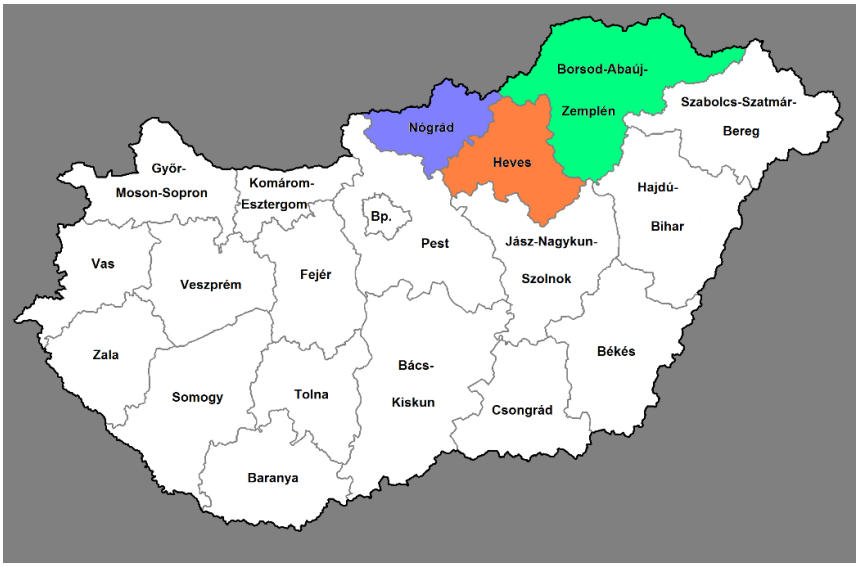

Figure 1. Geographical location of Borsod-Abaúj-Zemplén county
(Source: own work)

In the spirit of the above, the aim of the present research is to identify the location of ambulance stations in Borsod-Abaúj-Zemplén county (NUTS 3 region), in the region of Northern Hungary (NUTS 2 region) (figure 1), and to explore the contrast between the expectations formulated and the actual services provided. The county is the third largest in terms of area (7,250 km^2) and the second largest in terms of population in Hungary (according to 2011 cenzus ~680,000 inhabitants). As far as its settlement structure is concerned (Pénzes and Demeter, 2021), the northern

part of the county is characterised by a large number of small villages (Demeter and Radics, 2015), i.e. settlements with a population of less than 500 inhabitants each. This feature, combined with the mountainous topography of the region – Southern Bükk, Egri-Bükkkalja, Miskolc-Bükkkalja (Csorba, 2021) – and the resulting sparse road network, creates significant challenges in terms of optimisation and rationalization (Badar and Kozma, 2020; Molnár, 2017).

MATERIALS AND METHODS

The projection system used for the analysis is the Unified National Projection (EOV), which is represented in the ArcGIS software as "HD 1972 Egységes Orszagos Vetuleti", with EPSG (European Pertol Survey Group) code 23700. In terms of the software environment, Microsoft Excel was used to produce the charts and tables, and the software Calc from LibreOffice version 7.1 was also utilised. In addition, GIMP software version 2.10.24 was used for the subsequent modification of the maps (Makhlouf Adel et al., 2021)

The ambulance stations were shown on the map on the basis of a table provided by the National Ambulance Service (OMSZ), which not only shows the spatial location of the ambulance stations, but also the types and number of ambulances per station. The mapping of the settlements assigned to each ambulance station was also based on the data provided by OMSZ. The assignment of hospitals is based on data from the Hungarian Hospital Association and the National Hospital Directorate General (OKFŐ).

RESULTS

There are currently 21 ambulance stations operating in Borsod-Abaúj-Zemplén county (figure 2), of which 2 are type "C", 3 are type "B" and 16 are type "A" stations. The differences listed in Table 1 can be supplemented by the fact that the higher-ranking stations are equipped with ambulances providing more complex care. In contrast to the situation generally prevailing in Hungarian counties, where the highest level of service represented by type "C" ambulance stations located in the county seat, in Borsod-Abaúj-Zemplén county a station of this type also operates in Kazincbarcika, a town located about 30 km from Miskolc. The reason behind this is the fact that the chemical plant of Wanhua-Borsodchem Zrt. is located in Kazincbarcika, and because of the risk posed by this, a type "C" ambulance station was also set up in this town. Type "B" stations (Ózd, Mezőkövesd, Sátoraljaújhely) are located in towns at a greater distance from the county seat, mainly close to the county border, and their establishment is due to this geographical characteristic (providing a high level of service to areas further away from the county seat) and the large population of the settlements concerned. In addition to the ambulance stations, OMSZ also has an air ambulance base in Miskolc, which serves the whole of the North Hungary region.

Table 1. Characteristics of different types of the ambulance stations
(Data source: OMSZ)

Types of ambulance stations	Number of ambulances	Management
„C" type ambulance station	8 or more ambulances	ambulance station manager, chief nurse, garage-master
„B" type ambulance station	4-7 ambulances	ambulance station manager, technical supervisor
„A" type ambulance station	2-3 ambulances	ambulance station manager

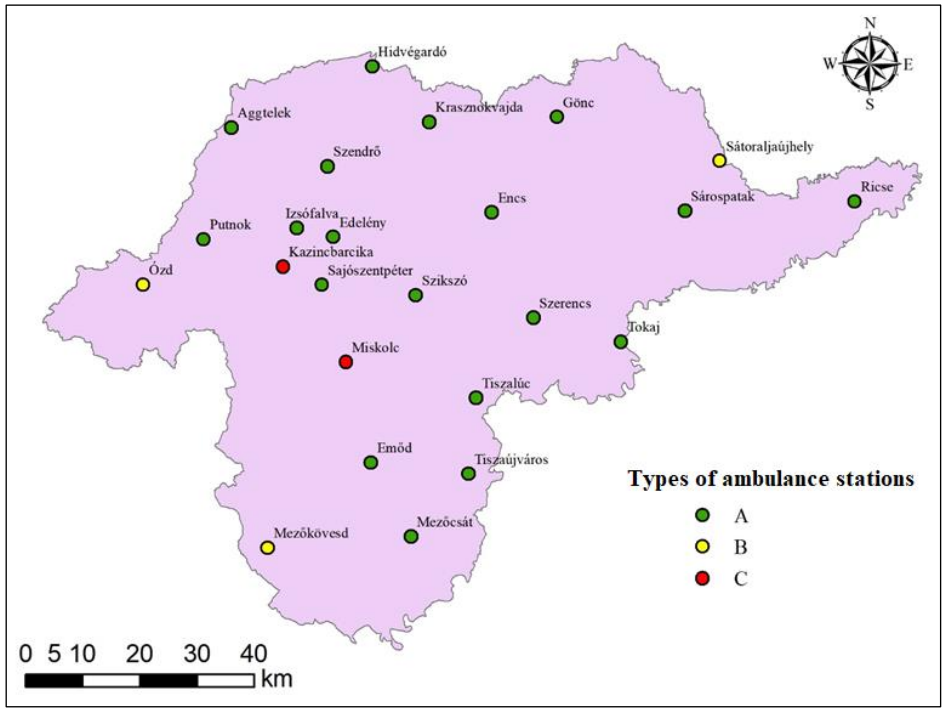

Figure 2. Geographical location of ambulance station in Borsod-Abaúj-Zemplén county
(Source: own work based on data of OMSZ)

The next stage of the research compared the official designated coverage areas of each ambulance station (figure 3) against the location of the ambulance stations that can be reached in the shortest time from each settlement (figure 4). The results showed that a total of 46 settlements were not in the coverage area of the ambulance station from which it could be reached in the shortest time. This figure represents 13.6% of the 337 settlements in the county potentially to be taken into account (there are a total of 358 settlements in the county, but we have to exclude the 21 settlements that have ambulance stations), so the two types of territorial delimitation are in fundamentally in harmony.

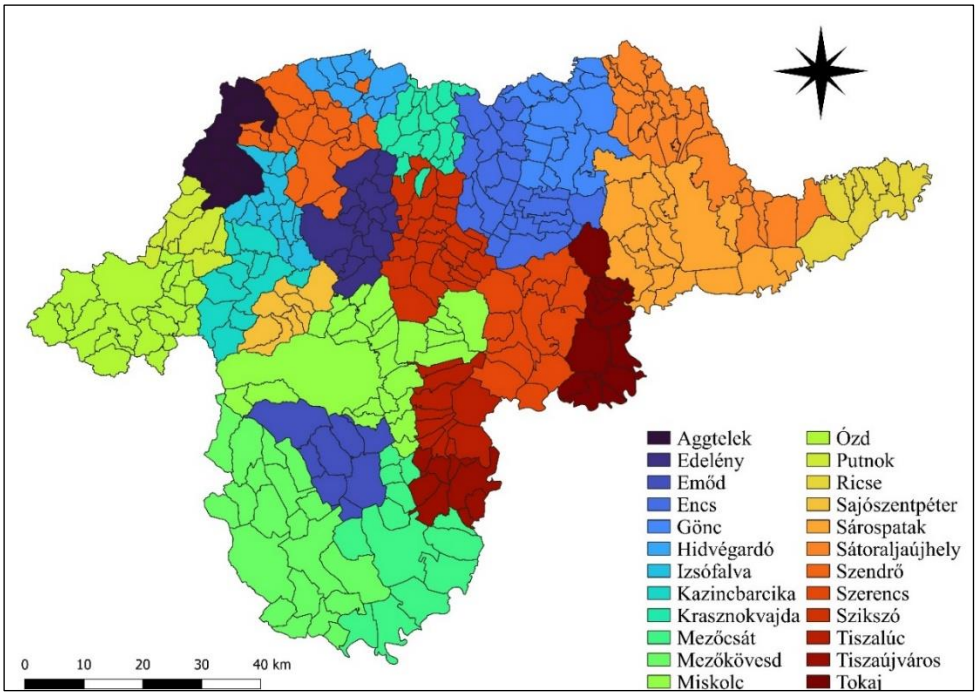

Figure 3. The official designated coverage areas of each ambulance station
(Source: own work based on data of OMSZ)

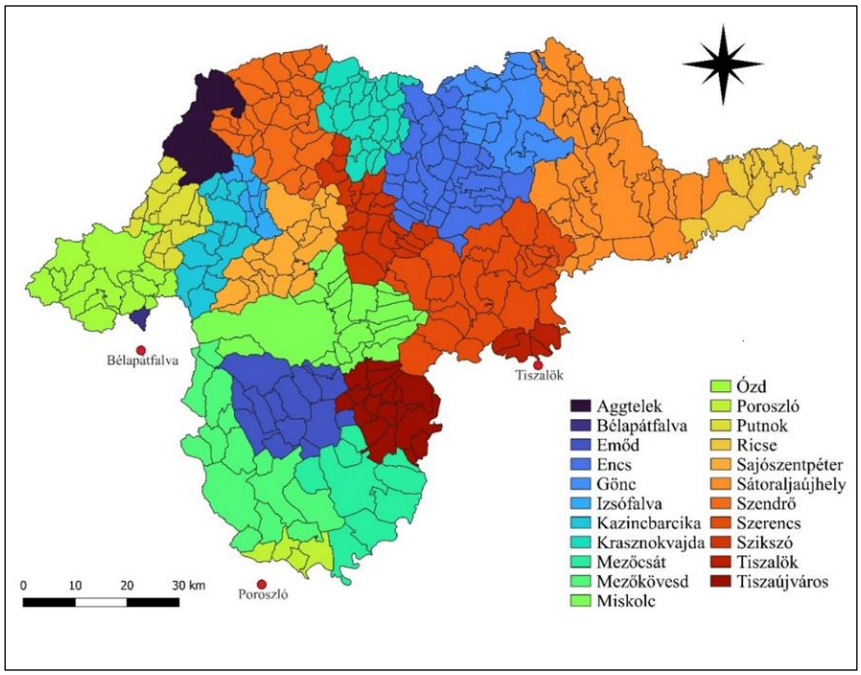

Figure 4. Coverage areas of each ambulance station designated by the shortest access time
(Source: own work based on data of OMSZ)

The highest "over-saturation" (where the number of settlements in the coverage area designated by OMSZ significantly exceeds the number of settlements that could be reached in the shortest time) can be observed in the case of Miskolc (19 settlements), followed by Mezőkövesd (7 settlements), Tokaj (6 settlements), Kazincbarcika, Mezőcsát and Ózd (5-5 settlements). Several factors are behind this phenomenon. Firstly, the majority of the settlements concerned have a type "C" or "B" ambulance station and, as a result, the official coverage area is larger than the number of settlements that can be reached most quickly from there (this is particularly the case for the two type "C" stations). On the other hand, the designation of the official coverage areas follows the county boundaries, but in some cases (e.g. Mezőkövesd and Tokaj) ambulance stations on the other side of the county line may provide faster access to certain settlements (in this case Poroszló and Tiszalök).

Nowadays, the official expectation for ambulance services is to reach the patient within 15 minutes of the emergency call. The current situation in Borsod-Abaúj-Zemplén county is very unfavourable: 81 settlements in case of a speed of 60 km/h, and 99 settlements in case of the highest possible speeds allowed by the Highway Code can be considered as uncovered (figure 5 and 6), and there are a total of 268,528 people living on the settlements in the former category. The difference between the two classifications is essentially related to the road network in the county (figure 7). On the one hand, the M3 runs along the southern/south-western half of the county, the use of which significantly improves accessibility to the areas located there. On the other hand, the northern part of the county is characterised by a network of small villages and a predominance of low-quality – or often even very poor quality roads – which do not make it possible to travel at 60 km/h.

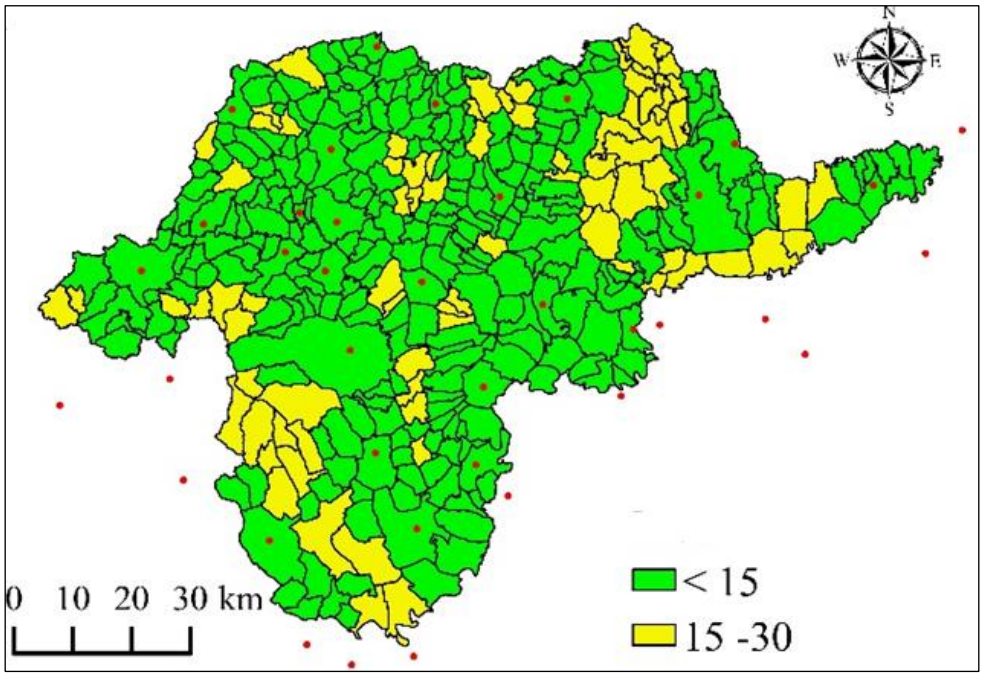

Figure 5. Access time (minutes) from an ambulance station to each settlements at a speed of 60 km/h
(Source: own work)

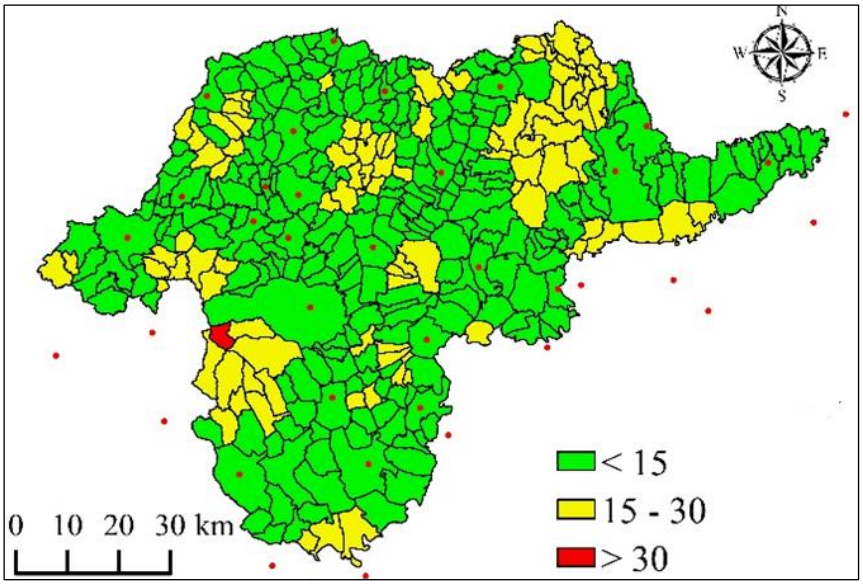

Figure 6. Access time (minutes) from an ambulance station to each municipality at the maximum speed allowed by the Highway Code
(Source: own work)

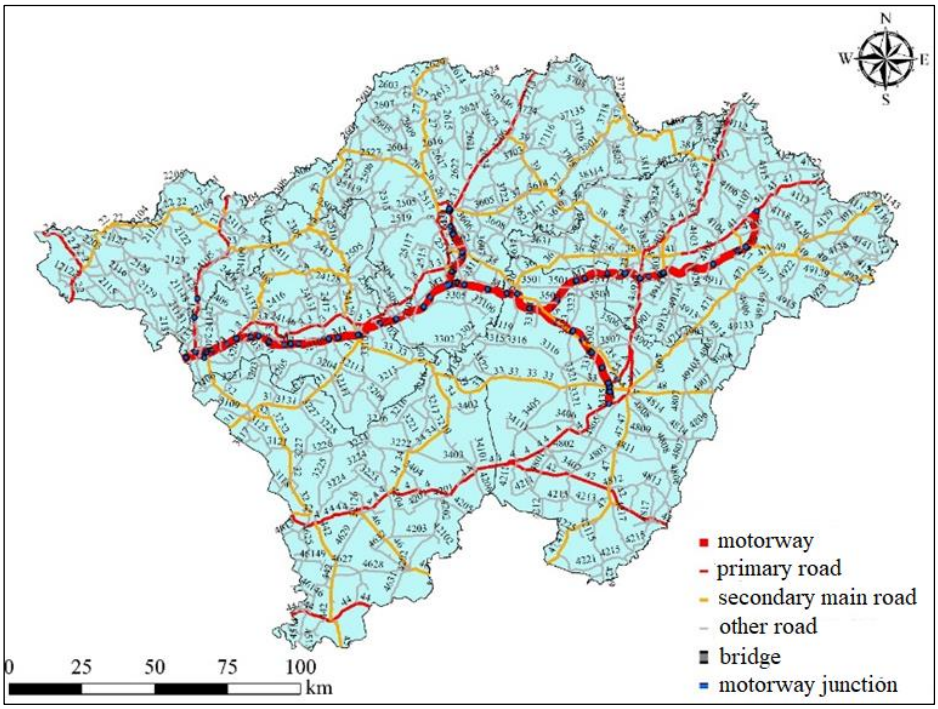

Figure 7. Road network of Borsod-Abaúj-Zemplén county and neighbouring counties
(Source: own work)

The transport of patients to hospitals is a very important task of the ambulance service and, as a consequence, the next section of the study addressed this issue. There are currently seven

hospitals operating in the county (figure 8), but the ones in Mezőkövesd and Szikszó do not have a department that would allow emergency care and were therefore not included in the study.

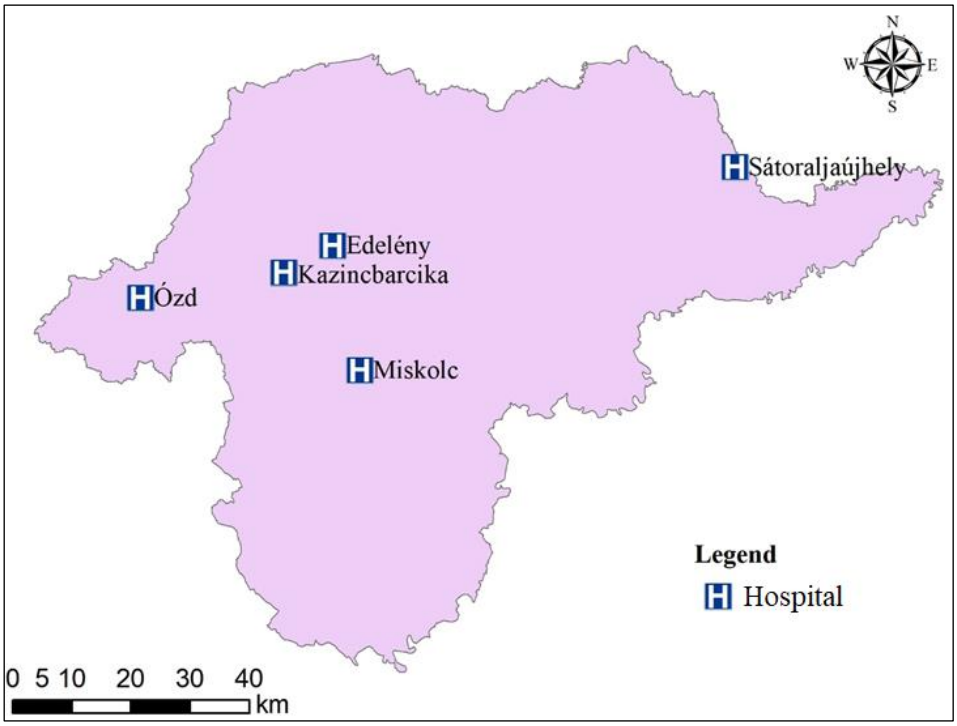

Figure 8. Hospitals that would allow emergency care in Borsod-Abaúj-Zemplén county (Source: own work)

An examination of the overall access time of each hospital (ambulance station to patient pick-up location to hospital) shows that the central and southern parts of the county are in a disadvantageous situation (figure 9 and 10). This is mainly due to the fact that these settlements are partly located far from hospitals and their accessibility is also hampered by the unfavourable topography (the Zemplén Mountains stretching in a northeast to southwest direction). The other important finding is that the total travel time to each settlement is lower in case of the speed allowed by the Highway Code (37.3 minutes) than in case of a speed of 60 km/h (39.4 minutes). This is due to the fact that connection with accessing hospitals, higher-ranking roads, such as primary and secondary arterial roads and motorways, are given priority, as they offer the possibility of travelling at higher speeds.

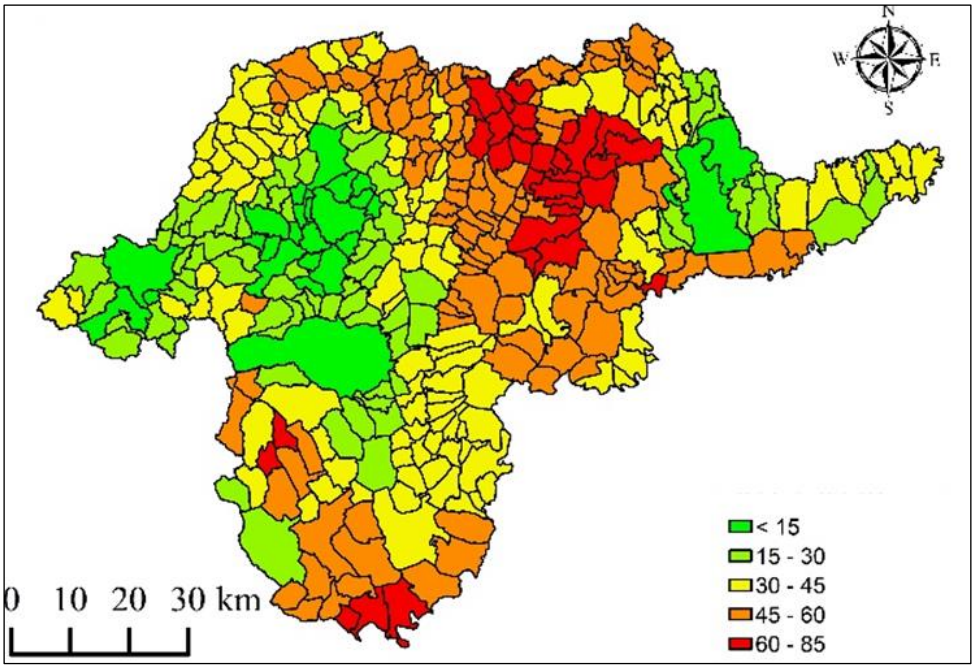

Figure 9. Total access times of nearest hospital (minutes) in case of a speed of 60 km/h
(Source: own work)

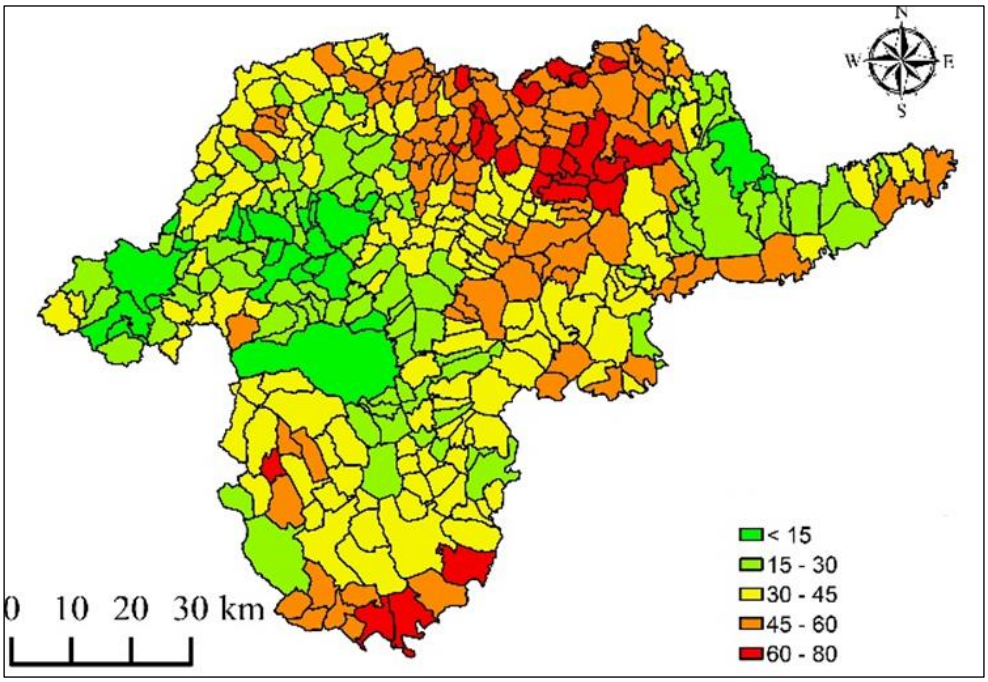

Figure 10. Total access times of nearest hospital in case of the highest possible speeds allowed by the Highway Code
(Source: own work)

CONCLUSIONS

The most important findings of the study could be summarised as follows. The geographical location of ambulance stations in the county is strongly influenced by geography and demographic characteristics. The designation of the coverage areas of ambulance station is fundamentally consistent with the access time to the respective ambulance stations, with major discrepancies observed mainly for stations providing higher-level services. The accessibility of each settlement from an ambulance station and the time required to travel the route of ambulance station to patient pick-up location to hospital differs in case a speed of 60 km/h and the highest possible speeds allowed by the Highway Code, which is primarily due to the geographical conditions and the characteristics of the road network in the county.

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