SPATIAL ACCESSIBILITY OF HOSPITAL HEALTHCARE IN ŁÓDŹ VOIVODESHIP

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Abstract: The article seeks to analyse the accessibility of hospital healthcare to inhabitants of Łódź voivodeship in 2015. The analysis comprises all the communes of the Łódź region as well as those of the neighbouring voivodeships from which the theoretical time of reaching hospitals in Łódź voivodeship does not exceed the maximum time assumed in the research. Accessibility was determined in reference to 51 hospitals, assuming that their 'attractiveness' was related to the number of permanent beds they offered. The research was conducted using the three-step floating catchment area method (3SFCA).

Key words: accessibility, hospital, Łódź voivodeship, 3SFCA

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Introduction

The problem of the accessibility of healthcare facilities has had a long history in geographical research (e.g. Morrill, Earickson 1968, 1969; Morrill, Kelley 1969, 1970; Morrill et al. 1970). The distribution of hospitals is a very important issue due to the health safety of inhabitants both at the regional and the national level (Wan et al. 2012). Spatial differences in accessibility are one of the indicators of the effectiveness of a healthcare system in places where it meets the transport system of a given area (Lou, Qi 2009). Consequently, a research into the accessibility of medical services, in this case of hospital healthcare, can be conducted on the basis of methods of spatial accessibility analysis (Lou, Wang 2003). Its results can serve as a rich diagnostic material for planning investments targeted at the health safety of inhabitants (Stępniak 2013). Conclusions drawn from these analyses can be used to introduce necessary modifications in relevant strategic documents, so that the implemented organisational changes can improve their health safety in the best possible way.

The article is devoted to determining and analysing levels of the accessibility of hospital healthcare to the inhabitants of Łódź voivodeship in 2015. The analysis comprises all the communes of the Łódź region as well as those of the neighbouring voivodeships from which the theoretical time of reaching hospitals in Łódź voivodeship does not exceed the maximum time assumed in the research, namely 30 minutes and 1 hour. Accessibility was determined in reference to 51 hospitals in Łódź voivodeship in accordance

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with the Operational Plan for Emergency Medical Services for Łódź voivodeship of June 23, 2015. The measure of hospital 'attractiveness' was the number of permanent beds which, in accordance with the report above, were available in those hospitals as of 31 December 2013. Data concerning the number of inhabitants of individual communes were obtained from the Local Data Bank of the Central Statistical Office. The research was conducted on the basis of a 3-step floating catchment area (3SFCA) (Wan et al. 2012), individual elements of which will be presented subsequently in the article. A dynamic development of a whole family of floating catchment area methods (such as 2SFCA, E2SFCA, O2SFCA, 3SFCA, extended kernel density 2SFCA) (Radke, Mu 2000; Lou, Qi 2009; Ngui, Apparicio 2011; Wan et al. 2012, Polzin et al. 2014) was possible due to the intensive development of GIS programming, particularly the functions concerning transport analysis.

The aim of this research is to specify how far the distribution and size of hospitals in Łódź voivodeship match the distribution of their potential patients from the perspective of communes. The introductory part is followed by ones characterising the hospital network of Łódź voivodeship, presenting the methodological approach to determining its accessibility, and finally describing spatial differences in hospital beds.

Hospitals in Łódź voivodeship

As was mentioned above, there are 51 healthcare entities in Łódź voivodeship which offer a total of 14,276 permanent beds. As many as 18 of them are located in the city of Łódź itself; this group comprises over 43% of all beds available. The largest hospital in Łódź is the Polish Mother's Memorial Hospital situated on the city's southern outskirts, whose wards have a total of 885 beds. The smallest in this respect is Dr H. Jordan's 4th Municipal Hospital with only 43 beds. Pabianice and Zgierz, located in the central part of the voivodeship, have two hospitals each. The biggest hospitals outside Łódź are John Paul II Provincial Hospital in Bełchatów with 795 permanent beds and the Wyszyński Independent Healthcare Institution in Sieradz, which together with the Centre of Interventional Cardiology and Angiology have 798 beds. Those are units situated in the southern and western parts of the voivodeship, respectively. The smallest entities, in turn, include the Independent Healthcare Institution at Pajęczno with 63 permanent beds, the Wyszyński Independent Healthcare Institution in Sieradz, the hospital in Rafałówka with 50 beds, and the Boruta Medical Centre in Zgierz with a mere 40 beds.

Looking at the map of the distribution of hospitals in Łódź voivodeship, it can be noted that it corresponds directly to the distribution of the region's settlement network and shows a similar relative regularity. Apart from a few exceptions, also the spatial distribution of the size of the facilities corresponds to differences in the number of inhabitants in individual centres (Fig. 1).

Since the article assumes that the journey to hospital is made by car, it seems justified to characterise the location of individual facilities in reference to elements of the main road network in the voivodeship. This, in all probability, will determine to some extent the final results of accessibility measurements. Due to the radial-concentric layout of the region's main roads, facilities in the centre of the voivodeship can be described as having the best location as far as transport is concerned (Wiśniewski 2015). Hence, in theory, hospitals in Łódź and its satellite towns seem to be most readily accessible from this perspective. Undoubtedly, the transport accessibility of individual areas of the Łódź region is largely influenced by the A1 and A2 motorways as well as the S8 expressway. Although the full positive impact of this type of infrastructure is visible at a supra-regional scale, it can be presumed that hospitals located in the closest vicinity of nodes on these roads will also display better accessibility levels.

Transport accessibility

The accessibility of medical services is one of the basic elements defining the standard of living (Stępniak 2013). When referring the notion of accessibility of such a specific service as healthcare, one should take into account at least two aspects: spatial accessibility and attainability (Drury 1983). This research leaves out a whole group of factors and barriers which decide about the levels of accessibility of medical services to focus

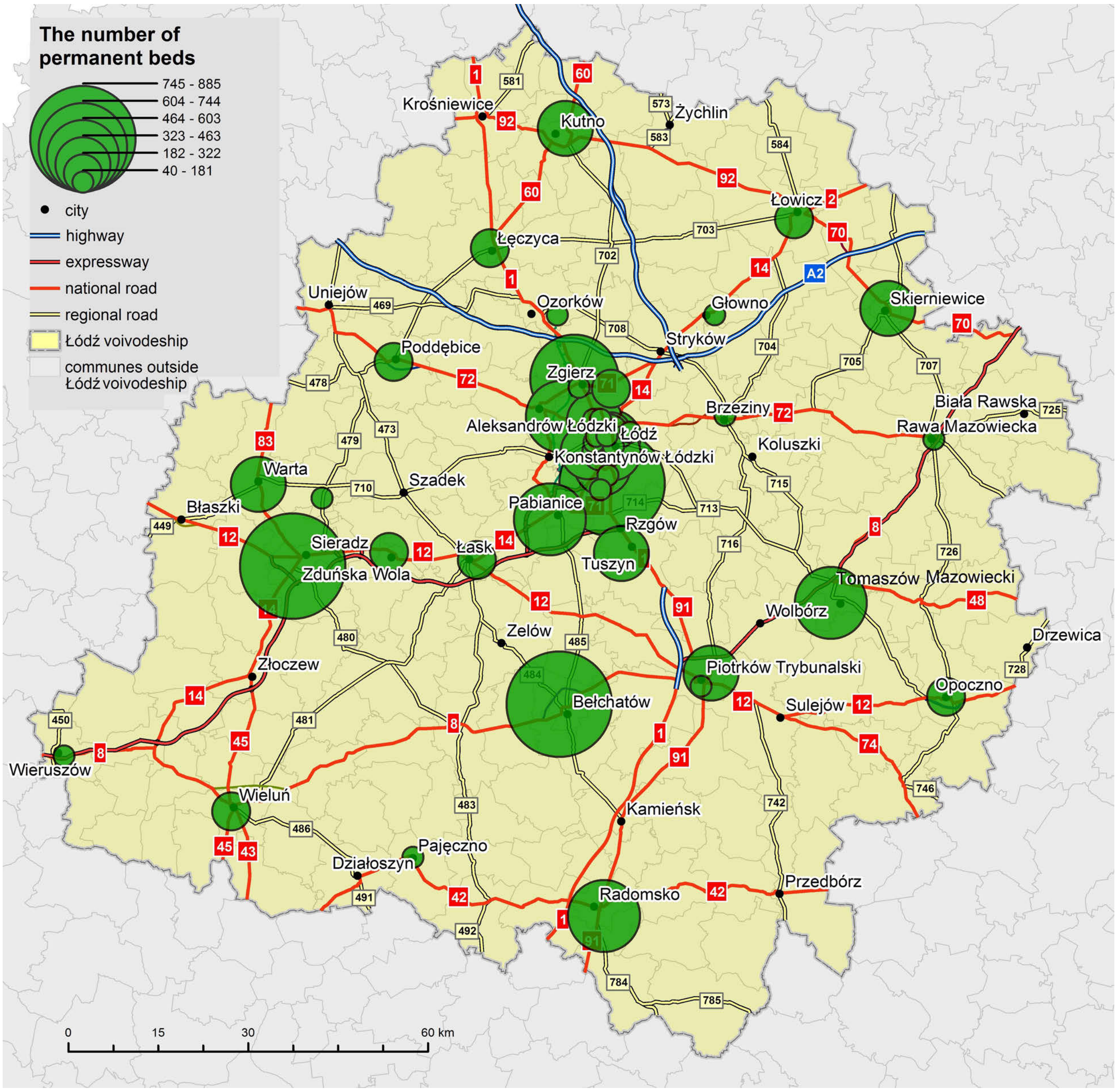

Fig. 1. Number of permanent beds in the hospitals of Łódź voivodeship in 2014.
Source: author's own work on the basis of the Operational Plan for Emergency Medical Services for Łódź voivodeship of June 23, 2015.

only on the relation between people's places of living (the distribution of the population) and the location of healthcare facilities, in this case hospitals. Wyszewianski (2002) interprets the notion of accessibility as the level at which the supply of services meets the demand for them in organisational, personal and financial terms.

When determining the transport accessibility of individual facilities, the principle adopted was that a potential hospital patient uses a personal car. The analysis included defining travel times between every commune of Łódź voivodeship and a group of communes belonging to adjacent voivodeships and every researched hospital. The incorporation of communes outside the voivodeship into the research was determined by their location within one-hour isochrones of access to individual hospitals. If a commune was located within the boundaries outlined by isolines of identical access times, it was included in the study. This was necessary in order to eliminate the effect of the voivodeship's 'artificial' administrative boundaries. The inhabitants of Łódź voivodeship, especially those living in the communes on its edge, can prefer to be treated in hospitals located in another voivodeship. Naturally, the opposite can happen when hospitals in Łódź voivodeship are attractive to inhabitants of other regions, which was taken into account by the adopted variant of the research. That is why, when scrutinising the results, it should be remembered that they may, to some extent, fail to reflect the reality.

The research assumes that the only factor determining a vehicle's speed is traffic regulations. When establishing the route between every commune-hospital pair, the shortest possible route was assumed. The travel time was measured from the commune's administrative boundary to the hospital car park.

When there was a node within a commune's boundaries making it possible to enter or exit a road of limited accessibility (motorway, expressway), the time measured was not that of travel to its boundary, but to the point at which it was possible to join traffic on this type of road.

In relation to the notion of accessibility understood as matching the offer of the provider to the needs of the client, one should bear in mind that this research embraced all permanent beds in a hospital irrespective of the ward where they were situated. This figure refers, on the one hand, in a way to the hospital's potential, although it does not reflect the level of the medical services it provides. On the other hand, the specificity of a facility is blurred as it can have a considerable number of beds allotted to a given profile of patients whose number in the region is rather small. This is the second element which may affect the accuracy of the research. It also gives a pretext for an in-depth analysis of the number of beds on individual wards in relation to the number of potential patients in terms of specific features, like age or sex.

The simplest method of research into relations between two points in space (i.e. a patient's place of residence and the location of a hospital) is to determine the Euclidean distance between them (Fortney et al. 2000), but this involves considerable discrepancies with reality. Although Lin et al. (2002) point out that deformations are particularly severe in mountain towns and areas, with such a limited scale of research as the one adopted in this work the results would probably also be deformed for Łódź voivodeship. A far more precise analysis consists in determining a real physical distance. Undoubtedly, it is a solution which reflects actual transport relations in an area in a more accurate manner, yet it is still far from the ideal. The most reliable projection of the existing differences is to measure the spatial accessibility of medical services by means of the time necessary to cover the distance between a patient's place of residence and a hospital (Martin et al. 1998).

Stępniak (2013) points to still another problem of differences of individual medical centres. The issue of accessibility disappears completely together with the measurement of the distance between the place of residence and the nearest medical facility. The weakness of this approach can be seen especially in urban areas as patients do not always use the services of the nearest facility, having a choice between medical centres situated at a similar distance from their place of residence (Goodman et al. 2003). It is inadvisable to base research on spatial accessibility or analyses of the distance to the nearest facility in all those places where it is possible that market areas (operating ranges) of individual facilities overlap (McGrail, Humphreys 2009). Another factor determining the accessibility of medical services is also the aforementioned quality (rank) of individual facilities, which can be manifested, for instance, by specialised equipment or qualifications of the personnel.

When considering the accessibility of hospitals, one must also bear in mind the function of space resistance. Together with a growing travel distance (in this study expressed as travel time) the number of interactions between the source (place of residence) and the destination (hospital) decreases and so does the attractiveness of the destination. Of course, the renown or specificity of a medical facility can be a feature powerful enough to overcome even a strong resistance of space. The decrease in the attractiveness of a destination is measured in accessibility models by the space resistance function. It can be assumed that for minimal-distance travel the attractiveness of the destination and at the same time the probability of travel is 100%, steadily declining to 0% together with the lengthening of the distance. In the opinion of Geurs and Ritsema van Eck (2001), the value of parameters by which the resistance function is measured depends on numerous factors (e.g. the transport branch, its type, the centre, motivation for travel, and naturally features of the patient and the attractiveness of the destination selected). Models of potential accessibility make use of the resistance function, for instance, the normal distribution function, log-normal distribution function, exponential function, log-exponential function, hyperbolic (power) function, power distribution function in logarithmic form, and the Gamma distribution (Chojnicki 1966). By far the most popular functions include power functions (Fotheringham 1982), exponential functions (Spiekermann, Schürmann 2007), the Gaussian distribution functions (Ngui, Apparicio 2011), and log-logistic distribution functions (Geurs, Ritsema van Eck 2001).

In this study space resistance was described using the exponential function. According to Geurs and Ritsema van Eck (2001), resistance functions which best show the real behaviour of users are the exponential and logistic distribution functions. The exponential function has also been used many times in pan-European research (e.g. Spiekermann, Schürmann 2007). For those reasons this work uses the exponential function because the research concerns both short journeys (where power and exponential functions perform better) and long ones (where the use of the exponential function or the sigmoid function seem more appropriate) (Rosik 2012).

Spatial differences in the accessibility of hospital beds

The analysis of spatial differences in the accessibility of hospital beds in Łódź voivodeship was divided into three stages connected with the research method employed. To minimise the problem of an overestimation of demand present in gravity models of spatial accessibility, this study uses a three-step floating catchment area (3SFCA) based on the most rational assumption of the demand for healthcare services. Generally speaking, it is assumed that the demand for the services of a facility expressed in population terms depends on the accessibility of other nearby places providing similar services. That is why in this model a weight based on travel time is assigned to every hospital-commune pair. This is an element extending the classic two-step method (2SFCA). The weight is subsequently used to measure the demand of the population of individual communes for medical services, eliminating normally existing overestimations.

The first part of the method is based on the determination of the impact area of every hospital, assuming the border value of travel time. In this study there are two variants: 30- and 60-minute travel time. For every hospital, isochrones of theoretical travel time were drawn, and travel time between a hospital and a point on the boundary of every analysed commune was delineated. It was assumed that the journey was made along a route ensuring the shortest travel time, and that the only factor determining the speed of a journey was traffic regulations.

Next, the author found all places where hospital services were provided for both delineated zones D (D_1 – 30-minute and D_2 – 60-minute) and allocated weights to both of them in accordance with the exponential function and the weight of choice between every hospital and commune in accordance with the following formula:

$$G_{ij} = \frac{T_{ij}}{\Sigma_{k\in[Dist(i,k)<d_0]} T_{ik}}$$

where:
G_{ij} – weight of choice in the relation between commune i and hospital j,
$Dist(i, k)$ – travel time from commune i to every hospital k,
d_0 – isochrone marking the zone of analysis,
T_{ij}, T_{ik} – weights in accordance with the exponential function assigned to j and k, respectively.

The employed function of space resistance is a fundamental issue determining the results of the accessibility model (Rosik 2012). The 3SFCA method, originally proposed by Wan et al. (2012), uses the Gaussian distribution, but this study employs the exponential function, most frequently used in empirical research in the form of the so-called natural exponential function, that is, an exponential function with the base equal to e, or the natural logarithm base. The formula for the exponential function of space resistance assumes the following form when used in research on accessibility:

$$f_{dd} = \exp(-\beta t_{ij})$$

where:
f_{dd} – function of space resistance,

t_{ij} – travel time between commune *i* and hospital *j*,
β – beta parameter.

The beta parameter was adopted from Rosik's work (2012) devoted to the overland accessibility of Poland's space. He calculated it on the basis of average travel times depending on travel motivation, assuming that it was to be determined in such a way that the attractiveness of the destination was about 1/2 for individual motivations to travel average distances. Journeys to hospital were qualified as short travel (the average travel time being 45 minutes), so the beta parameter equal to 0.0154 was used in the function of space resistance.

Subsequently, an indicator R_j was calculated for each hospital, representing its weight corresponding to the summed number of inhabitants (potential patients) living in communes located in the area delineated by the given isochrone:

$$R_j = \frac{S_j}{\sum_{\gamma=1,2} \sum_{k \in D_r} G_{kj} P_k W_\gamma}$$

where:
S_j – weight (number of permanent beds) of hospital *j*;
W_r – weight convergent with the exponential function appropriate for individual zones (D_1 and D_2),
G_{kj} – weight of choice in the relation between hospital *j* and population *k* of commune *i*,
P_k – population size *k*.

In the third part of the analysis, attention focused on communes where potential patients lived. As in the first stage, an area was delineated for every commune using the assumed borderline value of travel time to hospitals. Then the accessibility indicator A^F_i was calculated as the sum of R_j values obtained for all hospitals located in area *i*:

$$A_i^F = \sum_{\gamma=1,2} \sum_{k \in D_r} G_{ij} R_j W_\gamma$$

The 3SFCA method assumes that the demand for services provided in a place expressed in population terms is determined by the cost of travel (e.g. time) to this place and the cost of travel to other places providing services of the given kind. Consequently, the demand of a commune's population for services in a concrete hospital will theoretically decrease when other centres are accessible at the same level. This is reflected by the introduced weight G_{ij}. When a population has access to only one hospital, the weight will be equal to 1. With an increase in the number of hospitals available, this weight will decrease. Assuming that inhabitants of commune *i* have access to only one hospital *j* and the distance between them is 15 minutes, the product of G_{ij}, P_i and W_{ij} will assume the following form: (15/15) x 15 x P_i = 15P_i. When we assume that the offer of hospitals is increased to three (the distances being 15, 25 and 45 minutes), the product will assume the form: [15/(15+25+45)] x 15 x P_i = 2.65 P_i.

The employed floating catchment area method enables the inclusion of elements of both the supply of and the demand for medical services. It also allows considering the impact of a boundary on the accessibility of a facility in a neighbouring unit even when it is located in the vicinity of this boundary (Anselin 1988, Guagliardo 2004), the boundary itself not representing a barrier and having only an administrative character. The method also permits finding out to what extent the distribution of hospitals corresponds to the actual distribution of the population in individual communes. It is of importance particularly when analyses are based on data aggregated to spatially large units in which healthcare facilities are located on peripheries rather than in the centre (Geronimus et al. 1996). The method allowed identifying spatial differences in the accessibility of beds in the hospitals of Łódź voivodeship for the inhabitants of communes in this voivodeship.

The application of the research assumptions to actual conditions of the population distribution and hospitals in Łódź voivodeship permitted establishing the potential load of the hospitals in 2014 in terms of 30-minute and 60-minute access by patients (Fig. 2) as well as spatial differences in the accessibility of their services in terms of 30-minute and 60-minute access (Fig. 3).

On the assumption of a 30-minute journey by passenger car in accordance with traffic regulations, the hospital in Rafałówka, one of the smallest ones analysed, has clearly the highest load of potential patients. But one should bear in mind that this is a facility which has only a rehabilitation ward for children in its structure, hence it is of interest only to a part of the analysed population. By the criterion of the shorter travel time, there are three more facilities in Łódź characterised by a load above the average: Dr J. Babiński

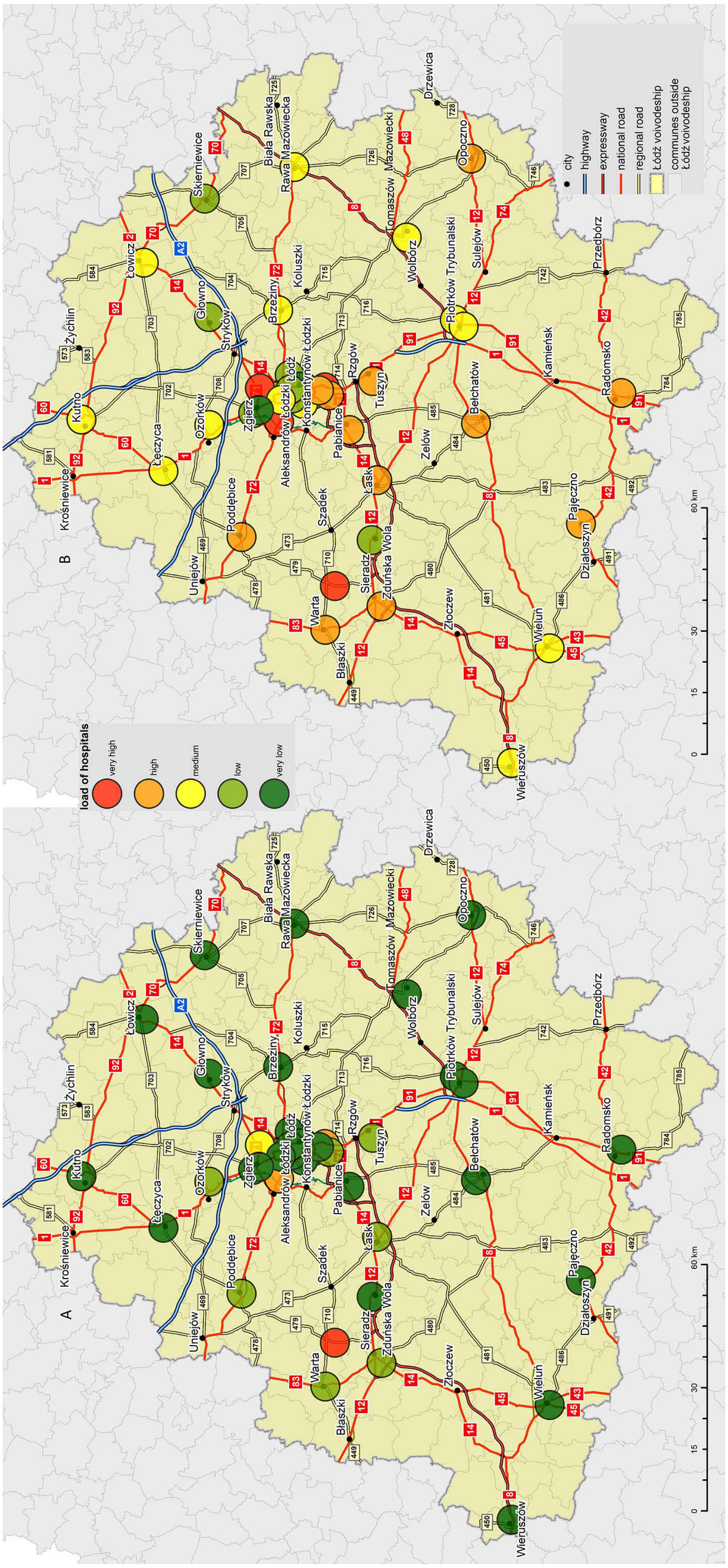

Fig. 2. Potential load of hospitals in Łódź voivodeship in 2014 in terms of 30-minute (A) and 60-minute (B) access by patients.
Source: author's own work.

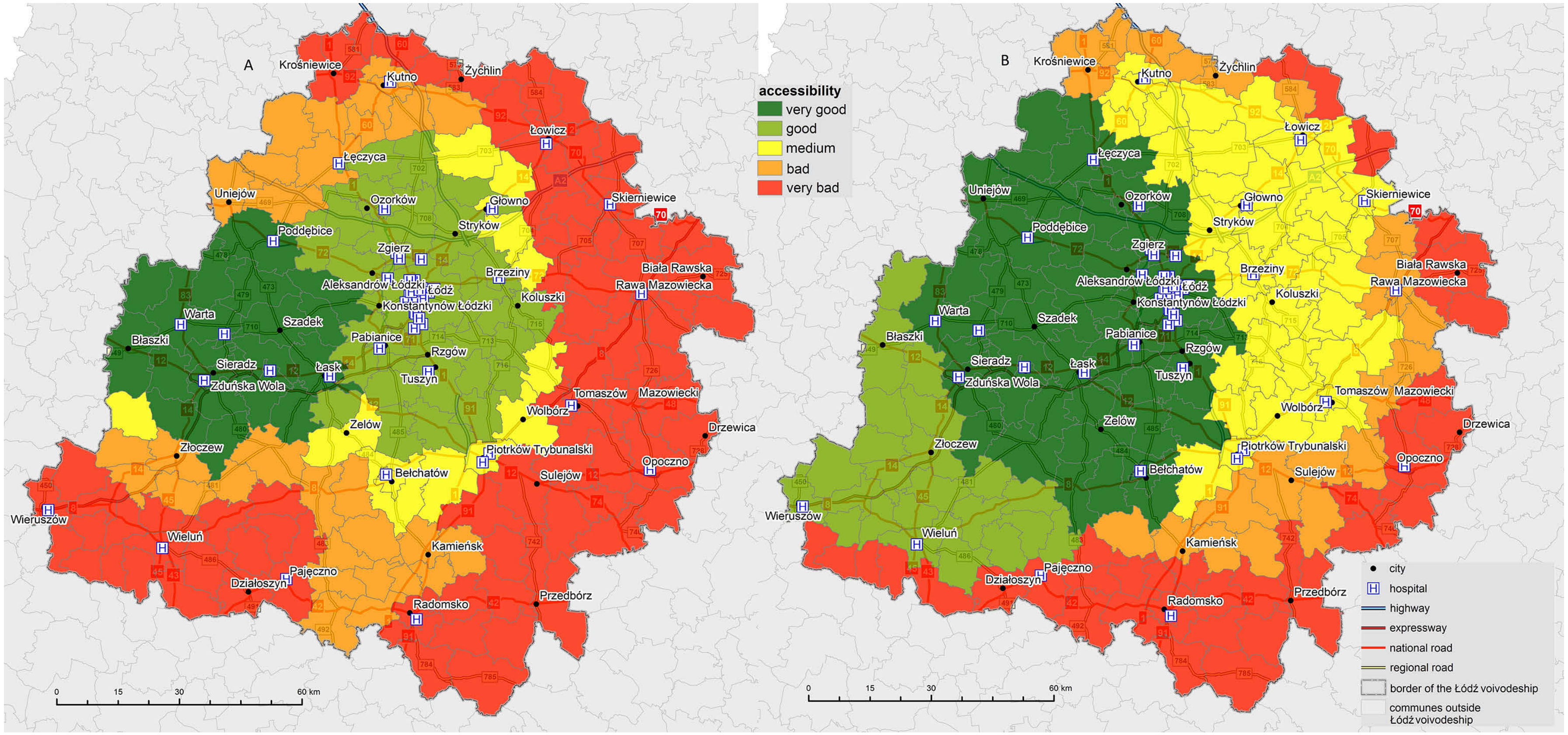

Fig. 3. Spatial differences in the accessibility of hospital healthcare in Łódź voivodeship in terms of 30-minute (A) and 60-minute (B) access by patients.
Source: author's own work.

Specialised Psychiatric Healthcare Centre, the Polish Mother's Memorial Institute, and the Voivodeship Complex of Healthcare Facilities – Centre for the Treatment of Lung Diseases and Rehabilitation. Even though they are large entities in terms of the number of permanent beds available, they can still be reached in 30 minutes by both, the inhabitants of Łódź and towns of large adjacent communes, such as Aleksandrów Łódzki, Konstantynów Łódzki, Pabianice or Zgierz, due to their peripheral location in reference to the boundaries of the city.

The situation of those facilities does not change after extending travel time to hospital to 60 minutes. Their theoretical load remains the highest of all the 51 units investigated. Some facilities have a load below the average: six hospitals in Łódź, the Wyszyński Independent Healthcare Institution in Sieradz, one of the largest in the voivodeship, the Non-public Healthcare Centre in Głowno, and the Polyclinic Hospital in Skierniewice.

Spatial differences in the accessibility of hospital healthcare in Łódź voivodeship generally assume the form of spheres. There are concentrations of communes characterised by similar accessibility levels both within a 30-minute and a 60-minute journey to hospital.

In the first variant, the communes in the western part of the voivodeship, including Łask, Wodzierady, Lutomiersk, Szadek and Zduńska Wola, have markedly the highest levels of healthcare accessibility. Accessibility above the average characterises communes in the centre of the region, including the city of Łódź. The worst situation is in some communes of Wieruszów, Wieluń and Pajęczno poviats as well as all poviats forming the region's eastern border. In turn, Cielądz and Sadkowice as well as the commune of Przedbórz in Radomsko poviat have markedly the lowest accessibility levels.

With the extension of the analysis to 1-hour travel time to hospital, the zone of the highest accessibility moves towards the centre of the voivodeship and extends longitudinally from Łęczyca poviat as far as Bełchatów poviat. In this group the highest accessibility levels can be found in the communes of Drużbice, Zelów, Buczek, Sędziejowice and Dłutów. The increase in the number of communes with good and very good accessibility, and especially those qualified as average, took place at the cost of the number of units with the worst parameters. In the case of 1-hour travel to hospital, the lowest accessibility levels can be found in the communes of Białaczów, Drzewica and Sadkowice.

Conclusions

The conducted research resulted in defining the extent to which the distribution and size of hospitals in Łódź voivodeship matched the distribution of their potential patients at the commune level. Generally speaking, this matching differs spatially. While the centre of the voivodeship and its western part are characterised by high levels of accessibility, the southern and eastern poviats should remain in the focus of attention. Naturally, their inhabitants can be treated in facilities situated in Opole, Silesia, Świętokrzyskie or Mazovia voivodeships, but with the study focusing on facilities in Łódź voivodeship the situation seems to require an in-depth analysis. It is not infrequently that the considerable distance between those communes and sparsely distributed hospitals, coupled with their low transport accessibility, represents a considerable barrier to potential patients living in them. A further research into their situation should be conducted, analysing the match between the profile of wards in hospitals which admit patients from this area and the profile of the patients.

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