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TRANSPORT ACCESSIBILITY OF SELECTED URBAN INTERCHANGES BASED ON THE EXAMPLE OF A LARGE CITY

Summary: The article presents an analysis of transport accessibility to selected urban interchanges in the city of Katowice. The method chosen for this purpose is the time accessibility measured by isochrones. The analysis was carried out for pedestrian movements and travelling by bus.

Keywords: transport accessibility, urban public transport, pedestrian movements, traffic engineering, road transport.

DOSTĘPNOŚĆ TRANSPORTOWA WYBRANYCH WĘZŁÓW PRZESIADKOWYCH NA PRZYKŁADZIE MIASTA DUŻEJ WIELKOŚCI

Streszczenie: W artykule przedstawiono analizę dostępności transportowej do wybranych węzłów przesiadkowych na terenie miasta Katowice. Wybrana metoda wykorzystana do tego celu to dostępność czasowa mierzona izochronami. Analizę przeprowadzono dla przemieszczeń pieszych oraz przemieszczeń wykonywanych komunikacją autobusową.

Słowa kluczowe: dostępność transportowa, publiczny transport zbiorowy, przemieszczenia piesze, inżynieria ruchu, transport drogowy.

1. Introduction

Various definitions of transport accessibility are available in the literature. One of them defines accessibility as the easiness of movement between two points based on the existing of transport infrastructure. It can also be defined as an indicator which determines the degree of transport development in a region or as one of the measures of transport assessment [1]. On the other hand, the paper [2] states that transport accessibility is determined by the way of spatial development, but also by the transport system. Besides, each person tasked with assessing accessibility would draw different

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conclusions depending on social affiliation (i.e. socio-economic characteristics) and travel time (i.e. time component).

In the literature of the subject, we can find a division into various methods of testing and measuring transport accessibility, including infrastructure-based accessibility measure, utility-based accessibility measure, potential-based accessibility measure, space-time-geography-based accessibility measure, distance-based accessibility measure, isochrone-based accessibility measure. In this work, the last of the mentioned method was used in the analyses. Accessibility measured by isochrones is accessibility measured by the range of comparable communication impact. The method of measurement is an estimate of the set of travel destinations available at a specified time or at a specified cost or effort of the journey. An example may be testing the accessibility of travel destinations using isochrones at a time distance of 5, 10, 15, 20 minutes from the source of travel [2]. Accessibility to a given point on the transport network can be analyzed by selecting a specific type of transport, e.g. car, tram, bus, truck. The selected method is also referred to in the literature as time accessibility if a unit of time such as minutes or hours is chosen as a measure of distance traveled. Transport accessibility as measured by isochronous means is commonly used in transport analyses due to its versatility and comparability. It provides the opportunity to analyze different spatial scales and different transport systems. This method is also one of the simplest ways to identify spatial accessibility [3]. In the analysis carried out with the use of this method, isochrones are performed, which determines areas of equal temporal accessibility. Classical isochrones represent time as a measure of distance. The isochrones themselves are defined as lines connecting points of equal time reach from a given point or set of points. Actual isochrones allow to presenting the zone from which the user will actually move in a specific time. When determining them, different speeds are taken into account, depending on the type of road or obstacles, which in turn causes the shape of the isochrone to curvature at its outer edges. The article presents an analysis of transport accessibility to selected six interchanges in Katowice. The time method measured by isochrones was used for this purpose. Actual monocentric isochrones were constructed. The type of transport for which the accessibility was analyzed was chosen the bus as an example of urban public transport and walking, which are the most frequently chosen non-motorized means of transport in cities.

2. Methodology of the study

The analysis of time accessibility requires the selection of the analyzed time ranges. These ranges were selected based on the results of pilot studies on the travel behavior of the population in Poland [4, 5]. The selection of time ranges took into account the diversity of areas on the maps. As a result, three measuring ranges were created for each type of displacement:

- walking accessibility - 5, 15, 20 minutes,
- accessibility of public transport - bus - 15, 24, 30 minutes.

The study on transport accessibility was carried out for Katowice as a large city. Katowice is inhabited by 292 774 inhabitants [6]. The capital of Silesia is one of the best-connected cities in Poland.

The city has well-developed public bus and tram transport, managed by the *Zarząd Transportu Metropolitalnego (ZTM)*. Some connections are serviced by the *Miejski Zarząd Dróg i Mostów* in Jaworzno (MZDiM). The network of tram connections is only in the northern part of Katowice. Transfer nodes in Katowice to which the accessibility was tested are:

- International Bus Station,
- "Piotr Skarga" bus stop,
- "Katowice Dworzec" bus stop,
- Brynów Passenger Transfer Center,
- Ligota Transfer Center,
- Zawodzie Transfer Center.

These points were selected for detailed analysis because they fulfill a transfer function and are critical points of passenger service in the city of Katowice. The main purpose of establishing transfer centers is to integrate public and individual transport, thus encouraging drivers to change the means of transport from a private (passenger) car to a tram or bus. For this purpose, large park & ride car parks have been built in the districts of Katowice Zawodzie and Brynów [7, 8]. The Ligota Transfer Center enables a quick change from public transport to the railway. All of the selected transfer centers, apart from the possibility of changing the means of transport to the bus, offer the possibility of using bicycle stands. Equipping transfer nodes with infrastructure for bicycles or bike-sharing stations additionally increases the accessibility of these points in the transport network [9].

The result of the analysis of transport accessibility to interchanges in the city of Katowice are maps with isochrones. These maps were made using the QGIS program and the ORS Tools plugin. Isochrones were created for the selected, previously mentioned points, separately for each type of movement - pedestrians and bus transport. Made monocentric, actual isochrones. Monocentric isochrones refer to one point once, not to a set. On the other hand, actual isochrones connect points with the same distance in time, taking into account the limitations in space, and therefore do not have the shape of a circle. The preparation of this type of isochrone allows for the presentation of areas with the same values, i.e. the same time reachability. In turn, the irregular shape of them will allow observing the actual limitations occurring in the field, in the form of e.g. railway tracks, closed areas, forest paths, buildings. The basis for determining the access zones was data obtained from OpenStreetMap.org.

3. Transport accessibility to selected urban interchanges

3.1. Pedestrian movements

Pedestrian accessibility maps for selected interchanges are shown from Fig. 1 to Fig. 6 (red points on the maps indicate locations of analyzed places). The isochrones show the 5, 15 and 20-minute accessibility areas. Figure 1 shows the walking accessibility to the International Bus Station.

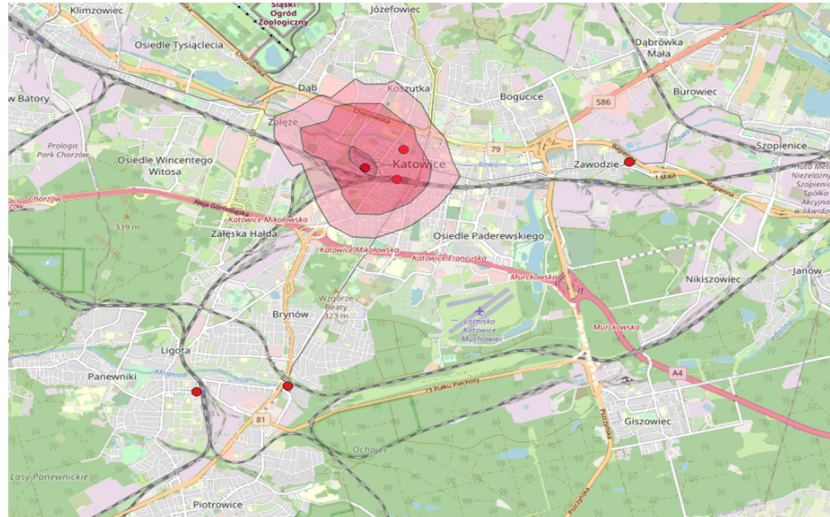


Figure 1. Walking accessibility to the International Bus Station

Based on Figure 1, it can be concluded that the pedestrian access to the Transfer Center on Sądowa Street is minimally limited. When you look at 5 minutes accessibility, the area is not circular, it is slightly flattened on the south and southwest side. Based on the land usage analysis, it was found that this limitation is due to the presence of a railway track, which is a physical barrier to accessibility. The same reason causes the deformation of isochrones for 15 and 20 minutes. On the south-west side, there is also a lower density of the road and street network. Fig. 2 shows the pedestrian access to the “Piotr Skarga” bus stop.

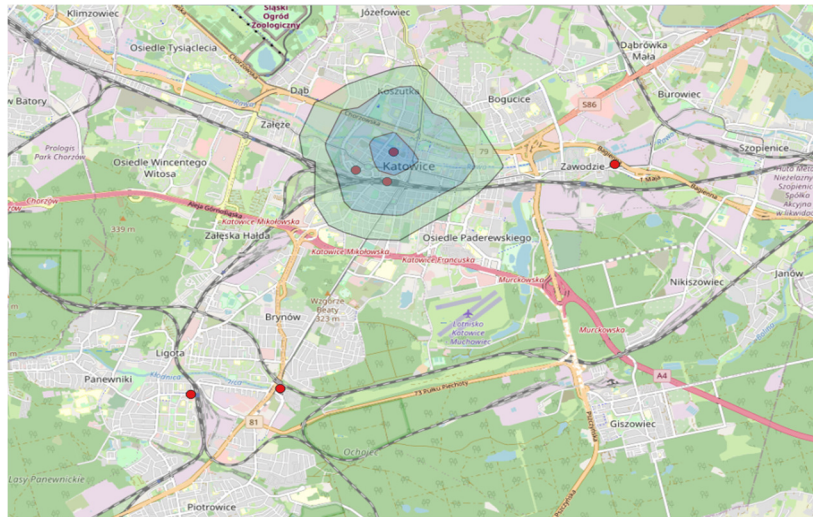


Figure 2. Walking accessibility to the “Piotr Skarga” bus stop

The pedestrian access to the Piotr Skarga bus stop (Fig. 2) is not particularly limited on either side. The shape of all areas is close to a circle. For the 20-minute interval, slight flattening can be observed from the north-east and south-east. After analyzing the spatial development of the studied area, it can be assumed that it is caused by the street layout in this part of the city and the presence of railway tracks (on the south side) and road No. 79 (in the northern part of this area). In the case of the accessibility isochrone for 20 minutes, the irregular shape of the isochrone is visible on the western side of the area. This shape is most likely due to the presence of railroad tracks contributing to reduced accessibility.

Fig. 3 show the walking accessibility to the “Katowice Dworzec” bus stop.

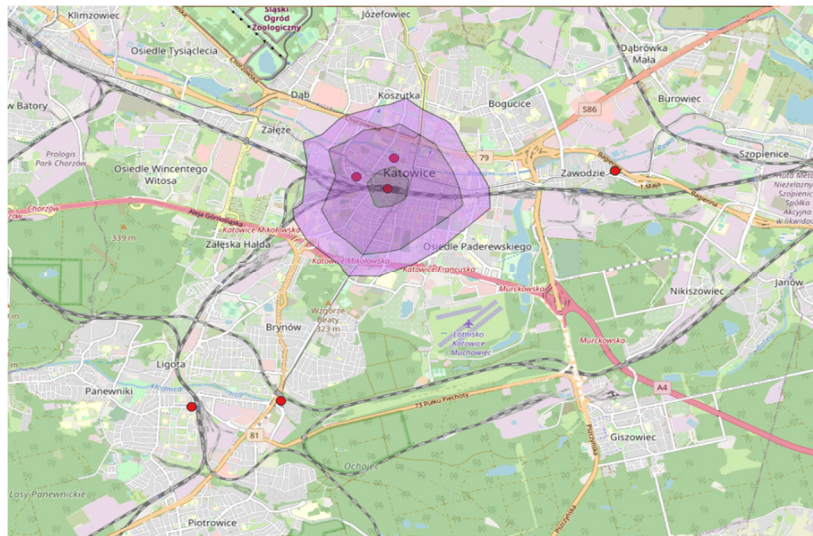


Figure 3. Walking accessibility to the “Katowice Dworzec” bus stop

The Katowice Dworzec bus stop (Fig. 3) is located under the railway station. The isochrone forming the pedestrian accessibility area within 5 minutes has the shape of an almost perfect isochrone. The remaining isochrones are irregular in shape. Protruding vertices are visible, probably because they are the end of the roads leading from the analyzed stop. From the east, there is an indentation (for the area of 15 and 20 minutes) caused by the presence of railway tracks. Bus stops Piotr Skarga's and Katowice Dworzec, as well as the International Bus Station, are close to each other, although the shape of the isochrones formed around them differs. Especially the shape of the isochrones around the International Bus Station differs from those around the stops. Due to such close proximity to important places in the transport infrastructure, they can complement each other and provide a greater choice of stop for public transport users. With their common range (20 minutes on foot) they cover the entire city center and also reach the neighboring districts of Katowice.

Figure 4 presents isochrones showing pedestrian access to the Brynów Transfer Center. The isochrones created around the Brynów Transfer Center (Fig. 4) have an irregular shape. In 5 minutes, we can get to the more distant point on the west side, as the area is more extensive in that direction. However, on the eastern and north-western side, the area is flattened. It was found that the cause may be the railway tracks on

that side limiting efficient movement. The 20-minute walking accessibility is also limited by the tracks, from the south-east and south-west.

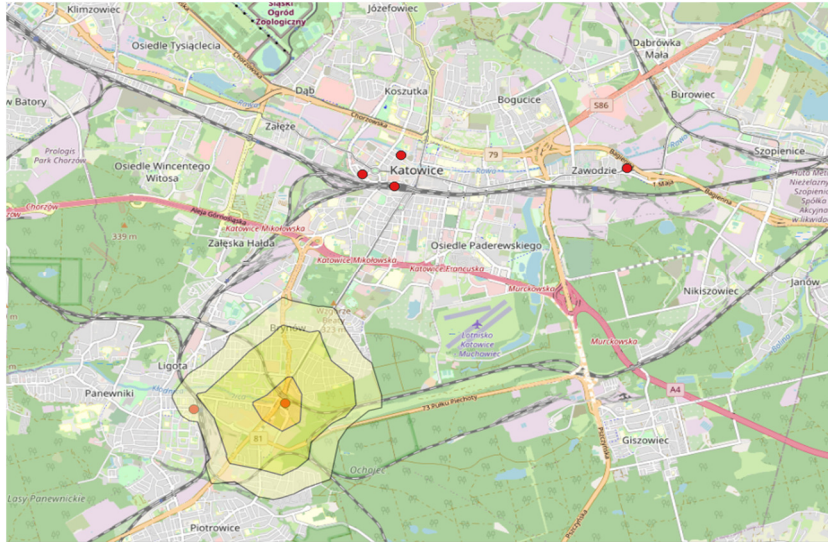


Figure 4. Walking accessibility to the Brynów Transfer Center

The transfer center is located at the intersection of four Katowice districts, so (in a 20-minute time interval) it occupies almost the entire inhabited area of the Brynów-Os Zagrebniok district, a large part of Piotrowice-Ochojec, part of Ligota-Panewniki and Zaleska Hałda-Brynów. It also reaches the Ligota transfer center with his range. This fact allows efficient walking from one interchange center to another.

Fig. 5 shows the pedestrian access to the Ligota Transfer Center.

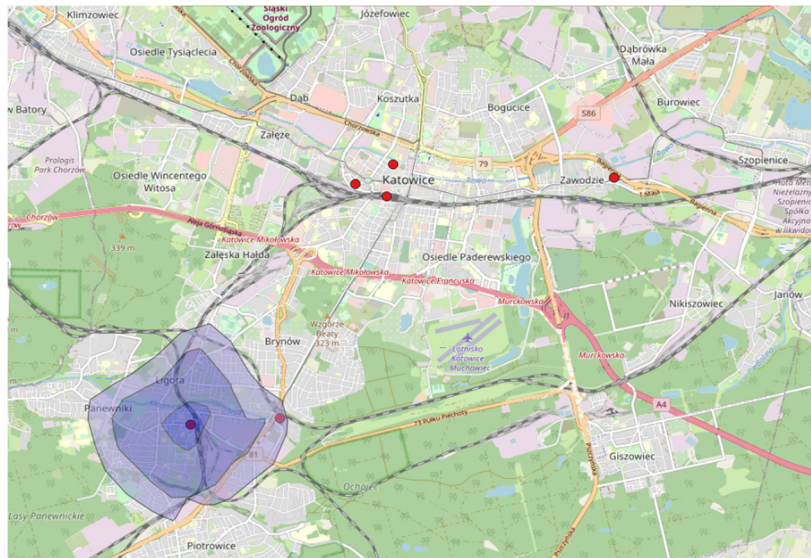


Figure 5. Walking accessibility to the Ligota Transfer Center

Pedestrian access to the Ligota Interchange Centre (Fig. 5) within 5 minutes from the south-eastern side is limited. This is due to the presence of railroad tracks. After a more detailed analysis, it was noticed that there is a railway junction there and there is no possibility of crossing to the other side in this area. The accessibility area within 15 minutes has an interesting shape, the main factor of which is certainly the road system, but also the Kłodnica river flowing in the area. It causes deformation and an indentation in the accessibility area 15 minutes from the eastern side. The isochrone for the time interval up to 20 minutes duplicates the smoother shapes of the isochrone 5 minutes smaller than itself, without the notch from the south. After the analysis, it was found that it is caused by more difficult access to this place because it is a closed area, developed with the buildings of a private company. The area covered by isochrones include only part of the Ligota-Panewniki district. The Ligota Transfer Center, opened in 2019, allows you to choose forms of transport such as train or bus, which can be used to travel longer distances. During a 20-minute walk journey, it is also possible to reach the adjacent Brynów Transfer Center, from which it is possible to choose a journey using a tram.

The Fig. 6 shows the pedestrian access to the Zawodzie Transfer Center.

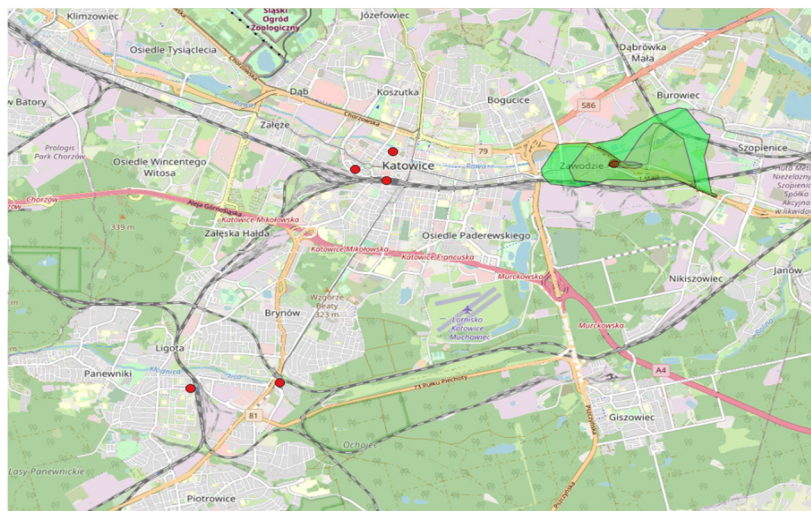


Figure 6. Walking accessibility to the Zawodzie Transfer Center

The shape of the resulting pedestrian accessibility area to the Zawodzie Transfer Center (Fig. 6) is the most unusual of all the pedestrian accessibility areas studied and presented in the article. The isochrones formed a surface flattened at the top and bottom with a practically small extent. The 5 min accessibility is very limited from West, North, and South. It was caused by a more complicated road system compared to the eastern side and the lack of road connections or their interruption in those directions. The area created for the time accessibility of 15 minutes is strongly limited from the south. This is due to the presence of green areas with a small number of paths and the presence of railway tracks. We can also observe flattening on the eastern side, caused by the lack of roads in that direction, and an unusual shape on the northern side - two "hills". After analyzing the facilities located there, it was found that the factor that caused this was, again, the lack of roads and paths, and the closed area

in the form of a public transport company. The Zawodzie Transfer Center is available within 20 minutes not only from the Zawodzie district but also from a part of the Szopienice-Burowiec district.

3.2. Travelling by bus

The accessibility of transport by bus to urban interchanges was analyzed regardless of the route of bus lines and the timetables. As a result of the analysis, the farthest area from which we can get by bus, without stopping at bus stops, to a given interchange was presented. The results of the analyzes are presented on the maps from Fig. 7 to Fig. 12. The isochrones show the regions of 15, 24, and 30 minutes accessibility. The area closest to the reference point represents accessibility in 15 minutes and the largest of them in 30 minutes. Figure 7 shows the accessibility of public transport to the International Bus Station.

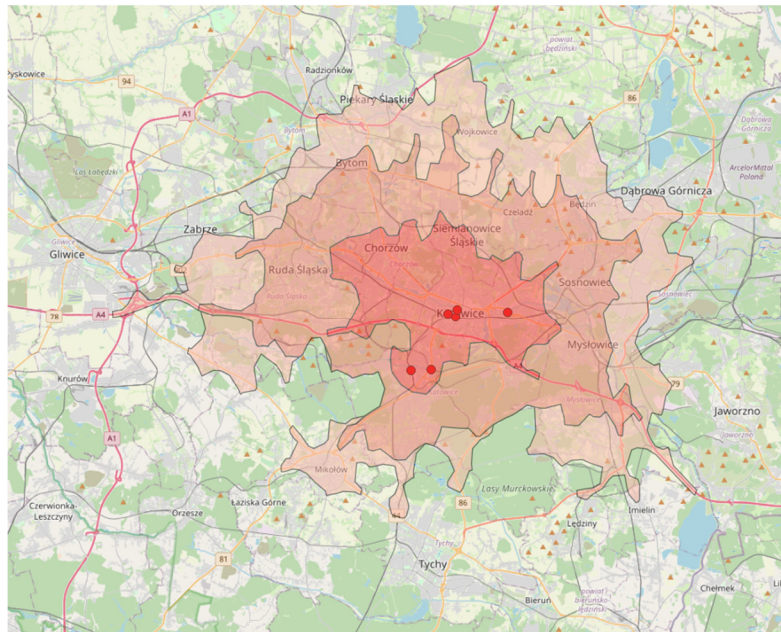


Figure 7. Bus accessibility to the International Bus Station

The bus accessibility to the Sądowa Transfer Center (also called the International Bus Station) within 15 minutes has an irregular shape. On the south side, it includes points marking the Ligota and Brynów transfer centers, because there is a dense network of roads leading to this area. On the other hand, there are noticeable indentations on both sides of this protrusion. The indentation located on the left side was created because there is a forest area with internal roads, and on the right, there is Katowice - Muchowiec airport and a road running south of it with a traffic ban. In the western part of the area you can see a bulge. It was created thanks to the dense network of roads. The city of Świętochłowice is located there. On the other hand, in the area showing accessibility in 24 minutes, numerous narrow protrusions can be observed (outside from the starting point), they are caused by single roads going in those

directions. It is especially visible in the northern part. This effect is more visible there because the remaining roads there are internal roads. Two notches are noticeable on the south side. The limitation in this area is caused by the Panewnickie Forests from the west and the Murckowskie Forests from the east. There are internal roads on them, therefore buses should not move on them. The same factor limits the accessibility area in 30 minutes. These are the most significant limitations of the largest analyzed area. Deformation can also be observed on the eastern side (east of Mysłowice in Fig. 7). The limitation in this area is the closed area in the form of private companies. In the vicinity of Dąbrowa Górnicza, the indentation is caused by railroad junctions, it is also an area through which two rivers flow and there is a forest. In Fig. 8 bus accessibility to the Piotr Skarga stop is shown.

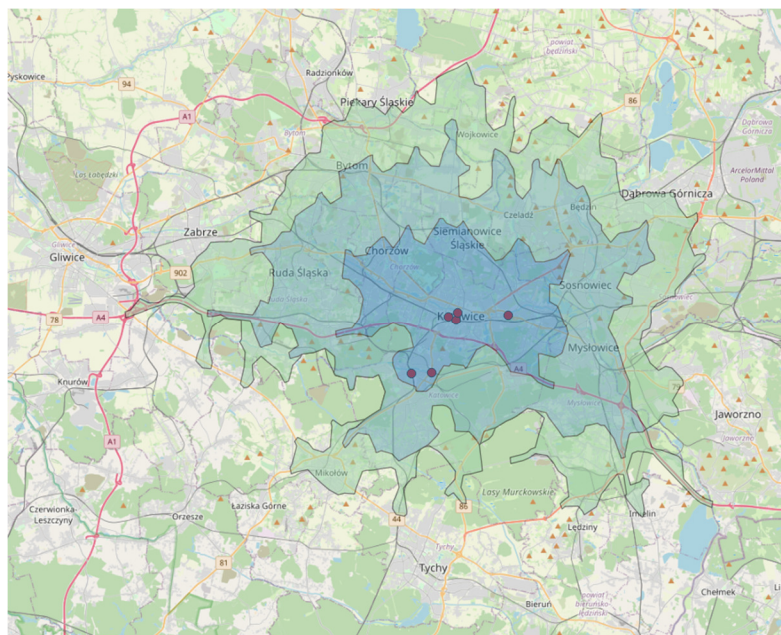


Figure 8. Bus accessibility to the "Piotr Skarga" bus stop

The area showing the accessibility of Piotr Skarga's bus stop within 15 minutes (Fig. 8) is limited in two places from the south. The cut to the south-west is caused by the forest, while the second one is due to the Katowice-Muchowiec airport, a road with a traffic ban and a forest. A semicircular recess is visible on the western side of the area. There are undeveloped areas, family allotments, and a forest on Mount Hugon. On the eastern side, at a similar height, can be seen a rectangular indentation. After analyzing the objects located there, it was found that it was caused by ponds, boulevards, and limited accessibility from the west side. The 24-minute accessibility is very unevenly shaped. Indentations are noticeable on the north side. Especially the two larger ones on the right were created due to the lack of public roads and the presence of fields. However, the entire area in that area is shaped like public roads run. Piotr Skarga's bus stop can be reached by public transport (bus) within 30 minutes from Dąbrowa Górnicza, Piekary Śląskie, or Mikołów, as shown in the largest area in Figure 8. Its shape is stretched in many places (single, narrow protrusions), caused

roads leading in those directions. Cavities in the area are also visible. The larger ones on the south side are caused by: Panewnickie Forests, Murckowskie Forests, and other forest areas. There is also a cavity visible in the east, created as a result of the closed area of private companies.

On the Fig. 9 shows the accessibility of public transport to the Katowice Dworzec bus stop.

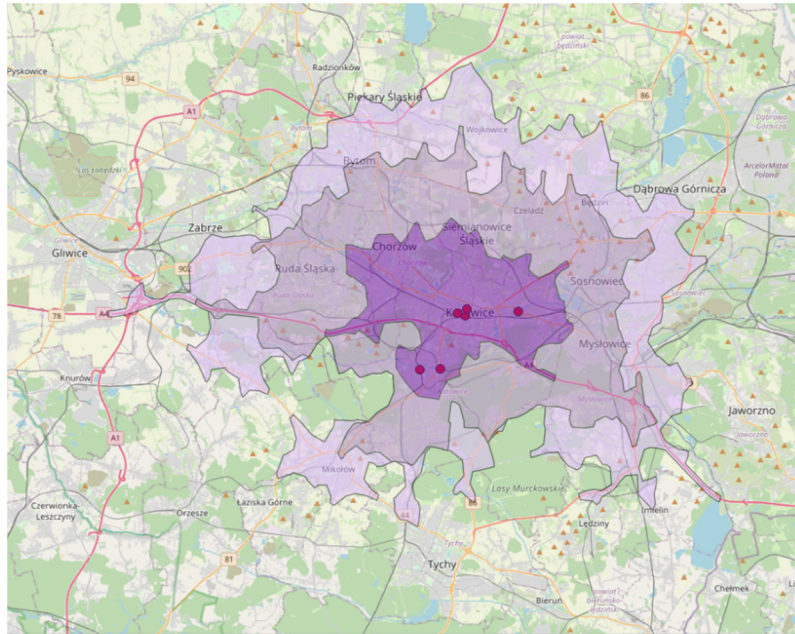


Figure 9. Bus accessibility to the Katowice Dworzec bus stop

The area showing bus accessibility to the Katowice Dworzec stop (Fig. 9) is very similar to the area shown in Fig. 7 regarding the accessibility to the International Bus Station. The same places create limitations and the same roads can be used to reach selected points faster (from further areas). This is due to the closeness of these points to each other. They are only 500 m apart, which is blurred on the scale of a bus trip in 15, 24, or 30 minutes.

On the Fig. 10, bus accessibility to the Brynów Transfer Center is shown.

The bus accessibility area within 15 minutes to the Brynów Transfer Center (Fig. 10) in the northern part is not deformed. This is probably due to the dense road network, as this area includes the center of Katowice. A concavity is visible on the west side. The reason for its creation is the Panewnickie Forests. They also deformed the accessibility area within 24 minutes. In the southern part of the areas marked in the drawing, there are Murckowskie Forests, which limit access to the transfer center within 24 and 30 minutes. This is one of the two greatest limitations to the analyzed point. In the area representing the time of 30 minutes, there is a noticeable indentation in the southern part, on the west from Tychy. There are forest areas, limiting due to the lack of paved public roads.

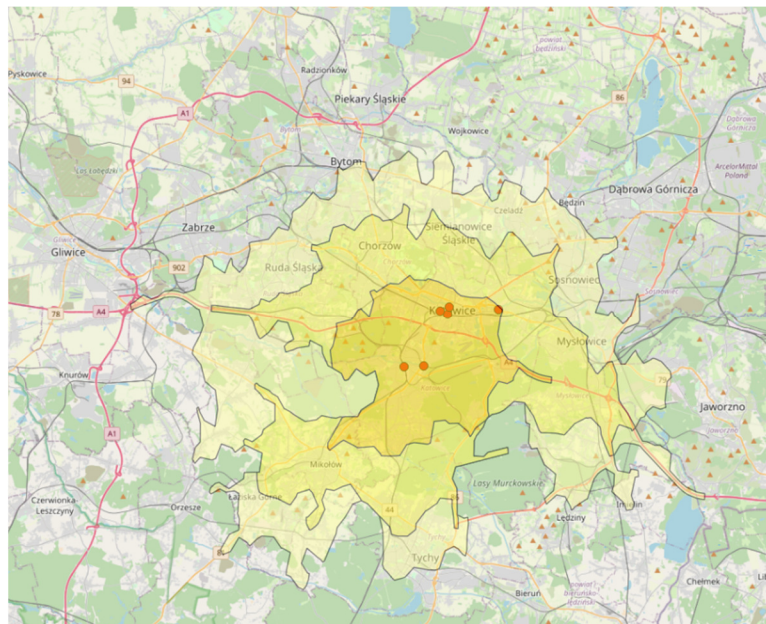


Figure 10. Bus accessibility to the Brynów Transfer Center

Moreover on the Fig. 11 shows the bus accessibility to the Ligota Transfer Center.

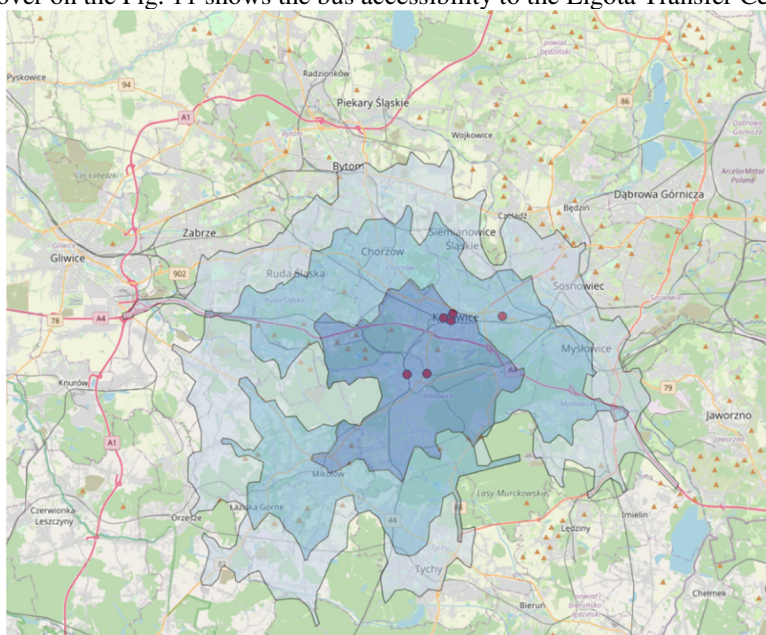


Figure 11. Bus accessibility to the Ligota Transfer Center

In the area created around the Ligota Transfer Center (Fig. 11), there are indentations especially on the west side, the north side (between Siemianowice Śląskie

and Czeladź), and two on the south side. The reason for such isochrones shape is the presence of forests and the lack of road infrastructure or its inadequacy for the movement of larger vehicles on them. In the places mentioned above, the restrictions are caused by: Panewnickie Forests, sewage treatment plant, and Murckowskie Forests. The 30 minute accessibility is also limited from the South East. A cavity caused by forest areas is visible there. In 30 minutes you can get to the Ligota Transfer Center from Bytom, Sosnowiec, Tychy, Orzesze. However, in 24 minutes from Ruda Śląska, Łaziska Górne, Mysłowice or Chorzów.

Bus accessibility to the Zawodzie Transfer Center is shown in Figure 12.

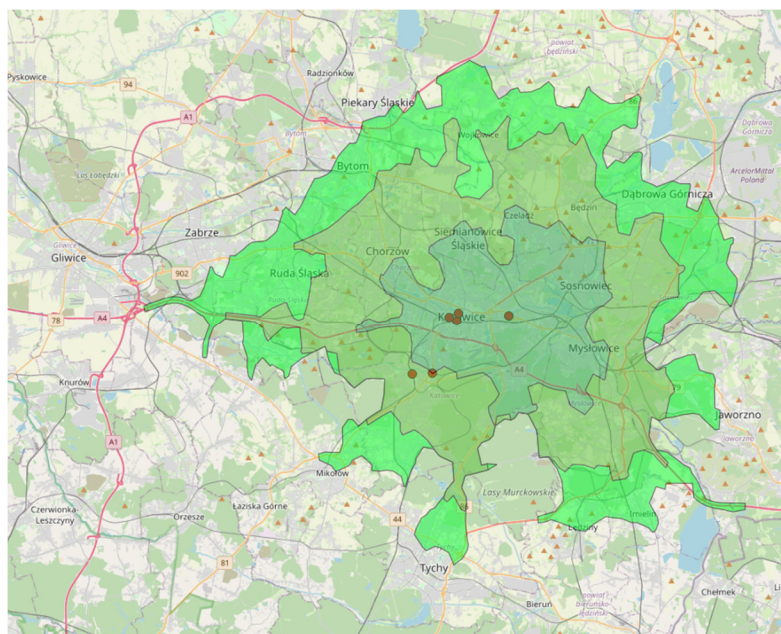


Figure 12. Bus accessibility to the Zawodzie Transfer Center

The 15-minute accessibility area (Fig. 12) is the smallest region. After analyzing its shape, many indentations were observed. The indentations on the north-west side result from the area of Park Śląski in Chorzów closed to car traffic, while the indentation on the right in Siemianowice Śląskie results from the fact that there is a sewage treatment plant, composting plant, and the area of the former heap with a network of paths surrounded by trees and shrubs. There is also a depression on the west side above the A4 motorway. This depression was created due to closed areas (i.e. private companies, municipal utility company, etc.), allotments, and a smaller amount of transport infrastructure suitable for traveling by bus. Another restriction located south of the A4 motorway is caused by the presence of forests and forest roads. From the south, the accessibility reaches the district of Katowice - Murcki. In the right and left part of the bulge there are forests. On the eastern side, between Sosnowiec and Mysłowice, the bulge is caused by the end of public roads in this place, because there is a Castle Park, a sewage treatment plant, and a wooded area there. Four larger indentations were noticed in the area of accessibility within 24 minutes. In the north, the reasons for which are the fields and the Brynica River. In the west, near Ruda

Śląska. In that area, there are many ponds, railway tracks, and Huta Pokój. In the south-west, there is Panewnicki Forest and in the south, where the Murckowski Forest is the limiting factor. The last two mentioned notches also appear in the accessibility area within 30 minutes. Within 24 minutes, the transfer center can be reached from Ruda Śląska, Będzin, Wojkowice. To travel from larger cities, such as Bytom, Dąbrowa Górnicza, or Tychy, you need more time, for example 30 minutes. In turn, on the eastern side of the 30-minute area, a larger indentation is noticeable. It occurs in Sosnowiec, there is a closed area within which many private companies operate and a larger area, which is subject to various types of waste disposal and storage facilities.

4. Conclusions

In the area of transport, analyzes of transport accessibility play an important role, as they allow to determine the efficiency of reaching specific points of the transport network. The article presents transport accessibility to selected six interchanges. Based on the analyzes carried out in the article, the following conclusions were formulated:

- factors that mainly limit pedestrian access are railroads, lower road network density, road system not conducive to quick access to the selected destination closed areas (i.e. motorways and expressways with a ban on pedestrian traffic),
- maps with isochrones allowed to state that there is limited pedestrian accessibility to the Zawodzie transfer center due to land development due to the lack of appropriate road infrastructure and the presence of railway infrastructure,
- the factors that mainly cause limitations in bus accessibility are the lack of roads in a given area, the presence of forest areas and parks, fields, closed areas e.g. company premises.

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