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COVERAGE OF DIGITAL PUBLIC TRANSPORT INFORMATION IN POLAND

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Abstract – Information is key in public transport (PT) systems because it influences their attractiveness. In recent years, there has been a trend towards digitization and opening up data related to the operation of PT. However, this progress varies from country to country. In this study, the authors analysed the availability of digital information on PT in Poland. For this purpose, 16 open data repositories and 22 commercial solutions were analysed. As a result, 66 open public transport data sources in GTFS format were retrieved, of which 48 were unique and up-to-date. The data included timetable information for 68 unique transport operators and nearly 50,000 stops, covering 35% of the built-up area in Poland. Additional information, e.g. on fares, was available much less frequently. The analysis of commercial solutions indicated that, in terms of the number of operators included, these solutions contain more data than open datasets. In terms of geographical coverage, the analysis was less conclusive. In addition, a rather limited number of commercial solutions tended to operate outside the largest cities. This makes planning journeys much more difficult in rural areas, with the passenger needing to have a good awareness of the planning solution to choose in a particular location.

Key words – public transport, information, open data, proprietary data, Poland

JEL Classification – C80, L91, L98, O18

INTRODUCTION

Information plays a significant role in public transport (PT) systems. Its accessibility, simplicity and legibility translate into ease of routing and subsequent monitoring and possible re-planning. PT information is categorised as a soft factor that contributes to the attractiveness of this transport system and allows an increase in its users, see e.g. [1-3]. Lack of access to information is also one of the factors contributing to transportation disadvantage and resulting in social exclusion [4][1].

The number of distribution channels for PT information is large, as there are tens of thousands of mobile applications of various kinds, and for a single city there could be as many as several dozen of such apps [5]. To effectively reach a large audience of potential passengers, PT providers must not only offer high-quality transportation services but also ensure that their information is accessible through various distribution channels and presented in a user-friendly format. Managing multiple information channels can be effectively facilitated by having a single digital dataset as the source of information for these channels. It is also important to maintain an open dataset, which means that it should be available for free data reuse, including for commercial purposes, under an open license. Moreover, it is recommended to ensure that the data can be updated via an automated process using an application programming interface (API) rather than relying on

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email correspondence with transport organizers. It is important to store the data in an open standard that enables machine processing [6]. When referring to an 'open standard', the authors imply that the specifications should be accessible by any entity without being restricted by the standardization body's decision. The most commonly used open digital standards for recording static information in public transport are:

General Transit Feed Specification[2] (GTFS), dating back to 2006. It was the effect of cooperation between TriMet (Portland, Oregano) and Google. According to the standard, information is exchanged through zip archives that contain separate txt files, each representing a different table. These tables are linked together using key fields. Certain tables and fields are required, such as the geographic coordinates of stops, while others, like information on the adaptation of stops for individuals with disabilities, are optional.

NeTEx[3] – the CEN technical standards utilized in various National Access Points for Multimodal Travel Information Services (NAP MMTIS) launched by EU Member States as well as other countries such as Norway. This standard involves the exchange of messages in XML format.

There are also equivalents of the above standards for real-time data (GTFS-RT and SIRI[4]) as well some others such as local standards developed in some countries prior to NeTEx, e.g. the British TransXchange[5].

It's important to note that the digitization and opening up of public transportation data vary between countries and even their regions. This study aims to evaluate the availability of digital PT information in Poland as of early 2023. The analysis considered both freely accessible open data sets as well as proprietary information that may require payment or have limited interfaces, restricting its potential uses.

1. Analysis of the availability of digital PT information in Poland – literature review

Previous research on PT information availability in Poland primarily focused on the application layer, which includes the accessibility of different distribution channels (e.g. [7-13]) focussing on cities like Lodz [14] or Cracow [15-16]. Gajda et al. [17] analysed the application of physical, digitalized information distribution channels (infokiosks, digital boards at stops) in the functional urban areas in Poland. The research however, was very limited as its results merely answered the questions whether such systems were or were not in place in the examined areas. Another analysis [18], that is relatively detailed, dates a few years back. It covered public transport in 35 Polish cities, but only analysed the websites and the accessibility from the perspective of 7 commercial applications. This research, like the previous ones, did not focus on the availability of digital data alone. The research by [19-20], that dealt with this issue, focussed on questionnaires completed by transport operators and did not evaluate the spatial availability of such data.

Polish GTFS data was also utilized in various research works, including exploring accessibility in functional urban areas in [17]. Moreover, studies were conducted on spatial or temporal accessibility in cities such as Cracow [21], Czeladz [22], Gdansk [23], Szczecin [24-25], and Warsaw [26]. Furthermore, the bike-sharing system in Poznan was analysed by [27]. Additionally, Cracow and Warsaw are two of the 85 cities analysed in terms of accessibility to rapid public transport systems in [28].

2. Materials and methods

Open data

To begin, the authors conducted an analysis of open digital datasets regarding the operations of public transportation in Poland. Their focus was on the availability of static data in the GTFS standard. The analysis was conducted from January to March 2023 and included a total of 16 repositories, consisting of 12 international and 4 Polish ones as listed in Table 1.

This group consisted of 8 MMTIS NAPs, namely Polish, Czech, Slovakian, German, Lithuanian, Latvian, and Estonian. Initially, the set only included Poland and its neighbouring countries. But, it was later expanded to cover the other Baltic States as well. This was done because in other sources there was valuable information on public transport routes between Poland and Estonia, while there wasn't any information regarding such routes between Poland and Latvia. The European Commission[6] website provided details about the location of NAP MMTIS for each country. The analysis covered both the old and new versions of MMTIS in Germany,

[2] https://gtfs.org/background/ (accessed 2023.04.30)
[3] https://netex-cen.eu/ (accessed 2023.04.30)
[4] https://www.siri-cen.eu/ (accessed 2023.04.30)
[5] https://www.gov.uk/government/collections/transxchange (accessed 2023.04.30)
[6] https://transport.ec.europa.eu/system/files/2022-11/its-national-access-points.pdf (accessed 2023.04.24)

while the Slovak MMTIS was unavailable due to an error (Error 503 - Service Unavailable). It's worth noting that certain NAPs had data in the NeTEx standard available simultaneously. The Polish NAP MMTIS had even more diverse data, with providers declaring the standard used themselves. In addition to static GTFS, data was available in the NeTEx standard from two IT integrators (InnoBaltica and przyjazdy.pl) and TransXchange from two cities (Rzeszów and Głogów, which also declared the GTFS format). Seven entities declared dynamic data, all using GTFS-RT (Głogów, Poznan, Cracow, Oborniki, Bielawa, PKS Poznań, and mKuran aggregation service for Ełk, Warsaw, and Warszawska Kolej Dojazdowa), with none declaring to use the SIRI standard. It's worth noting that datasets presented in formats like xls, pdf, csv, or xml without a specific standard were rejected for not meeting the openness requirement. Moreover, it's important to acknowledge that declarations of dataset availability in MMTIS PL were not always followed through with actual availability.

Table 1. Analysed data repositories

Name	Web address
mobilithek.info (NAP MMTIS DE)	https://mobilithek.info/
mdm-portal.de (NAP MMTIS DE2)	https://service.mdm-portal.de/mdm-portal-application/
datové sady (NAP MMTIS CZ)	https://data.gov.cz/datové-sady
odoprave.info (NAP MMTIS SK)	https://odoprave.info/wps/portal/pub
Data.gov.sk (NAP MMTIS SK)	https://data.gov.sk/
visimarsrutai.lt (NAP MMTIS LT)	https://www.visimarsrutai.lt/gtfs/
lvceli.lv (NAP MMTIS LV)	https://lvceli.lv/en/road-network/statistical-data/transport-sector-open-data/
peatus.ee (NAP MMTIS EE)	https://web.peatus.ee/
Krajowy Punkt Dostępu do usług informacji o podróżach multimodalnych (NAP MMTIS PL)	https://www.gov.pl/web/infrastruktura/krajowy-punkt-dostepu-do-uslug-informacji-o-podrozach-multimodalnych-kpd-mmtis
Otwarte Dane (Poland's Data Portal)	https://dane.gov.pl/
mKuran	https://mkuran.pl/gtfs/
Przyjazdy.pl (previously gtfs.pl)	https://przyjazdy.pl/gtfs
Mobility Database	https://database.mobilitydata.org/
Transitland	https://www.transit.land/
Transitfeeds	https://transitfeeds.com/
Openmobilitydata (OMD)	https://openmobilitydata.org/

Out of the seven repositories that the authors knew of, which had data about the Polish area, it was found that *openmobilitydata.org* and *transitfeeds.com* had the same datasets. To look for more sources, a Google search was done by asking questions about distributions in a particular standard, like 'GTFS in Poland.' It is worth mentioning that the GTFS repository curated by Kujala et al. [29] does not have any data about a single Polish locality.

The extracted datasets were then subjected to content analysis for timeliness, quality, completeness and redundancy. Sources were considered up-to-date if the calendar data they included (the ones contained in the *calendar.txt and calendar_dates.txt* files) covered the day the source was retrieved. The quality analysis included basic error checking. Necessary corrections were made if errors were found in the location of stops or the encoding of Polish characters. In the case of completeness analysis, the availability of optional information was checked, i.e. the detailed routing of transport lines (file *shapes.txt*), possible interchanges at nodes (file *transfers.txt*), charges (files *fare_...*), basic wheelchair accessibility information (*wheelchair_accessible* field in file *trips.txt* and *wheelchair_boarding* field in file *stops.txt*) and advanced accessibility information, i.e. files *pathways.txt* and *levels.txt*. Redundancy was tested for duplicate route data, which was identified by analysing the overlap of routes performed by the same agencies within different sources. Duplicates were removed by deleting data from sources that carried less information.

For the data prepared in this way, the quantities of the included agencies, routes and stops were taken for each source, as well as the median weekday frequency. The values for the number of routes were given as estimates,

sometimes as a range of values. This is because the division into routes is used in Poland for local transport, but in the case of non-urban agglomeration railways the numbering of individual trains is used. In addition, the GTFS standard is flexible enough to allow line variants to be stored in different ways - in a *routes.txt* or *trips.txt* file. As a result, in some cases the actual number of routes was difficult to estimate, making it necessary to support with the values of individual fields, e.g. determining the number of unique values for the *route_short_name*, *route_long_name*, *trip_headsign* or *trip_short_name*.

As GTFS sources are characterised by different timetable expiry dates (usually from a few days to a few months), instead of aggregating the number of trips in the source, it was decided to determine the median daily trip frequencies between the aggregated stop nodes. The statistical tools available in QGIS (determination of median values) and the GTFS-GO plug-in for QGIS (aggregation of stops to nodes and determination of trip frequencies between them) were used for this purpose. Aggregation to nodes followed the GTFS-GO plug-in algorithm based on name proximity and geographical coordinates. As a result, stops in both traffic directions were usually recorded for one node, but sometimes larger groups were included, e.g. all bus and tram stops at roundabout inlets. The determined frequencies refer to one-way trips, except when a vehicle stops several times within one node - then the frequency describes trips between any two stops of that node. A working day - Wednesday - was selected as the day of analysis.

The forms of data licensing were also analysed. Noteworthy is the fact that the datasets extracted from the Polish NAP MMTIS often did not have an indicated licence. However, the Ministry of Infrastructure itself, in the report accompanying the implementation of the NAP [30], cites legal regulations and case law indicating that PT information is public information - at least as far as the routing of transport lines and timetables is concerned. Hence, the data reported to this repository was treated, as open.

To evaluate the accessibility of public transportation (PT) information in different voivodeships, the authors identified four indicators. The first indicator considered the number of active stops in each voivodeship, meaning stops that have at least one PT line assigned to them. The second indicator was the number of active stops per 1,000 inhabitants. The third indicator was the proportion of the built-up area within 1 km of an active stop. Finally, the fourth indicator was the percentage of municipalities (gminas) without any active stops, which are referred to as PT 'white spots'. Independently, the availability of information on cross-border trips was analysed which was determined as the daily number of trips (in both directions on a weekday) per 1 km of the national border length. The calculations were based on demographic data provided by the *Statistics Poland* (*GUS*)[7], as well as by *Head Office of Geodesy and Cartography* (*GUGiK*): *National Register of Boundaries* (*PRG*)[8] and *Database of General Geographic Objects* (*BDOO*)[9].

Finally, a comparison was made between the number of stops available in the sources analysed and the number of stops obtained after merging the sets of *Topographic Objects Database* (*BDOT10k*)[10] and *OpenStreetMap* (*OSM*)[11], i.e. the two largest open data sets in Poland, which contain (among others) data on the location of stops.

PROPRIETARY DATA

As part of the proprietary data analysis, 22 IT service providers were analysed (see Tab.2), which may constitute assistance to the passenger planning the route, but are not necessarily limited to such applications. The set included the most popular solutions identified in the literature (see chapter 1) and on *Reddit* (*r/Poland* and *r/Polska*). Only solutions operating in more than one town were considered. Therefore, solutions such as *Mobill* (Wroclaw) or *Krakow Pod Reka* which are dedicated to single towns were not taken into account. In addition, the set includes solutions to support route planning for local transport. Quite a few solutions dedicated to trip planning and ticket purchasing for international, inter-regional and regional transport were omitted, such as those available on the websites of rail and bus operators, PT infrastructure managers or such websites as *Infobus*, *Koleo* and *Bilkom*. It should be noted, however, that timetables of the main railway companies (such as *PKP IC* or *POLREGIO*) and international bus companies (*Flixbus, Sindbad* or the ones available on *Infobus*) or even some of the more local ones are also available in Poland in some of the analysed solutions, e.g. *Google Maps*, *TravelTime*, *jakdojade* or *KiedyBus*.

[7] https://bdl.stat.gov.pl/bdl/start (accessed 2023.05.23)
[8] https://www.geoportal.gov.pl/dane/panstwowy-rejestr-granic (accessed 2023.05.23)
[9] https://www.geoportal.gov.pl/dane/baza-danych-ogolnogeograficznych-bdo (accessed 2023.05.23)
[10] https://www.geoportal.gov.pl/dane/baza-danych-obiektow-topograficznych-bdot (accessed 2023.05.23)
[11] https://www.openstreetmap.org/ (accessed 2023.05.23)

Table 2. List of analysed commercial PT information service providers

Name	Web address
AutobusowyRozkładJazdy	http://autobusowyrozkladjazdy.pl/
BusLive	https://buslive.pl/
Czynaczas	https://czynaczas.pl/
e-podróżnik	https://www.e-podroznik.pl/
Gdziejestautobus	https://gdziejestautobus.pl/
Google Maps	https://www.google.com/maps
Jakdojade	https://jakdojade.pl/
Jedzie	https://jedzie.pl/
KiedyBus	https://www.kiedybus.pl/
KiedyPrzyjedzie	http://kiedyprzyjedzie.pl/
mobileMPK | rozkładzik	https://www.mmpk.info/ | https://www.rozkladzik.pl/
Moovit	https://moovitapp.com
mPasażer	http://mp-technology.com/
myBus online	http://www.taran.com.pl/mybusonline/
rozklad.com	http://rozklad.com/
take&drive	http://takeanddrive.eu/
Time4BUS	https://time4bus.com/
Transportoid	http://transportoid.com/
Trapeze	https://trapezegroup.pl
Trasownik	https://www.silesiatransport.eu/
TravelTime	https://traveltime.com/
VOOOM	https://www.vooomapp.com/

As was the case with the analysis of open sources, it was also noted here that some sources offered real-time data on the location of public transport vehicles. However, as previously, here too the authors focused on the availability of static data. Their availability was assessed in two ways - by the number of available PT operators and authorities, and by spatial coverage - whether a service operates within a municipality. The analysis was based on the declarations of the providers, and these were briefly verified by filtering out duplicates and records suggesting that a particular carrier, authority or service in a particular location is not functioning (e.g. has been suspended). In the absence of an outright indication by a given provider, it was assumed that the carrier/organisation in question operates only in the area of its local municipality. What is more, it was only the urban municipality if the urban and rural municipalities shared the same name. A similar assumption was made when providers indicated the localities where their services were available. A different approach was taken in the case of *Google Maps*, for which neither a list of entities nor a list of localities was found. In order to assess the availability of data in this solution, 313 of the largest Polish cities - with more than 5,000 inhabitants - were manually (via the webmap user interface provided) reviewed for the availability of local transport. Accessibility was determined if stops with connected timetables were present on the map. In particular, stops were sought in the vicinity of town centres and railway and bus stations. It should be noted that due to the different analysis method of *Google Maps*, it was not included in the analysis of the number of entities included. The assessment in this case is even more difficult, as the timetable data used in *Google Maps* can come from PT authorities and carriers, but also from aggregators such as *Infobus*. Similarly, due to insufficient data availability, the analysis of spatial accessibility coverage did not take into account *e-podróżnik* and *AutobusowyRozkładJazdy*. These entities declared the head office addresses of the carriers, which was considered too much of a simplification to be able to use this data for research purposes in this study. Carriers can operate out of their registered area and at the same time not operate in their registered regions.

3. RESULTS

OPEN DATA

For the open, static GTFS data, 66 source sets were acquired. Of these, 48 were selected for further analysis, see Tables 3 and 4.

Table 3. Results of the GTFS open source review – basic charasteristics

GTFS source name	No. of agencies	Estimated No. of routes	No. of stops	Median frequency	Transport category
PKS Poznań	1	100	914	5	Regional bus
Koleje Małopolskie ALD	1	22	1718	6	Regional bus
Öffentlicher Nahverkehr DE	2	87	1254	6	Reg.bus /local
Białostocka Komunikacja Miejska	1	46	994	46	Local
ZDMiKP Bydgoszcz	1	59	1170	46	Local
UM Czestochowa	2	36	924	39	Local
ZKM w Elblągu	1	20	436	34	Local
MZK Ełk	1	16	292	10	Local
ZTM Gdansk + ZKM Gdynia	2	167	2647	44	Local
GZK Bystry (Giżycko)	1	26	91	2	Local
GZM	1	447	7056	31	Local
ZTM Kielce	1	54	1287	21	Local
KPA Kombus (Kórnik)	1	11	233	5	Local
MPK Kraków bus	1	229	3045	33	Local
MPK Kraków tram	1	27	345	298	Local
ZTM Lublin	1	73	1242	31	Local
KM Łomianki	1	3	75	10	Local
MPK ZB w Łomży	1	13	190	21	Local
MPK-Łódź Spółka z o.o.	1	123	2253	56	Local
ZDZiT Olsztyn	1	35	537	65	Local
ZTM Poznań	11	176	2931	37	Local
MZDiK Radom	1	30	712	47	Local
ZTZ Rybnik	1	41	617	17	Local
ZTM Rzeszów	1	60	890	36	Local
ZDiTM Szczecin	1	96	1635	53	Local
KA Świnoujście	1	8	166	16	Local
UM Toruń	1	45	702	36	Local
Warszawski Transport Publiczny	1	336	7158	63	Local
MZK Wejherowo	1	17	356	26	Local
MPK Włocławek	1	26	300	32	Local
UM Wrocław	6	127	2265	69	Local
MZK w Gorzowie Wielkopolskim	1	42	490	17,5	Local
Szybka Kolej Miejska	1	9-278	35	113	Local rail
Warszawska Kolej Dojazdowa	1	3	28	85	Local rail
Vbb.de (local PT component)	3	3	14	21	Local PT
Vbb.de (rail component)	2	5	3	17,5	Rail
Koleje Małopolskie SKA	1	14	125	11	Rail
Koleje Dolnośląskie	1	21-38	276	9	Rail
Koleje Mazowieckie	1	55	517	16	Rail
Koleje Wielkopolskie	1	493	248	10	Rail
Łódzka Kolej Aglomeracyjna	1	99	182	10	Rail
Koleje Śląskie	1	109	203	14	Rail
PKP IC	1	481	449	4	Rail
Polregio	1	2399	1855	7	Rail
nvbw.de	2	3	4	10	Rail
Železničná spoločnosť Slovensko	1	5-10	27	1	Rail
Flixbus-EU	1	147	212	2	Intl. Bus
peatus.ee	1	1	39	1	Intl. Bus
visimarsrutai.lt	1	2	8	1	Intl. Bus
Overall	71	6447-6738	49150		

Table 4. Results of the GTFS open source review – licences and availability

GTFS source name	Licence	Available in repository
PKS Poznań	NAP*	NAP PL
Koleje Małopolskie ALD	CC BY 4.0	NAP PL
Öffentlicher Nahverkehr DE	CC BY 4.0	Transitland / NAP DE
Białostocka Komunikacja Miejska	NAP	NAP PL
ZDMiKP Bydgoszcz	NAP / CC0	NAP PL / mKuran
UM Czestochowa	NAP	NAP PL
ZKM w Elblągu	Source / authority specific	przyjazdy.pl
MZK Ełk	CC0	mKuran
ZTM Gdansk + ZKM Gdynia	CC BY 4.0	mKuran / OtwarteDane
GZK Bystry (Giżycko)	CC0	mKuran
GZM	OD 2.1	mKuran
ZTM Kielce	Source / authority specific	mKuran
KPA Kombus (Kórnik)	Source / authority specific	NAP PL
MPK Kraków bus	NAP	NAP PL / OMD
MPK Kraków tram	NAP	NAP PL / OMD
ZTM Lublin	CC0	mKuran
KM Łomianki	CC0	mKuran
MPK ZB w Łomży	CC0	mKuran
MPK-Łódź Spółka z o.o.	Source / authority specific	przyjazdy.pl
ZDZiT Olsztyn	PD	NAP PL / mKuran
ZTM Poznań	Source / authority specific	NAP PL/mKuran/OMD
MZDiK Radom	CC0	mKuran
ZTZ Rybnik	CC0	mKuran
ZTM Rzeszów	Source / authority specific	OMD / mKuran
ZDiTM Szczecin	NAP	NAP PL/mKuran/OMD
KA Świnoujście	CC0	mKuran
UM Toruń	NAP / CC0	NAP PL / mKuran
Warszawski Transport Publiczny	Source / authority specific + ODbL	NAP PL / mKuran
MZK Wejherowo	CC0	mKuran
MPK Włocławek	CC0	mKuran
UM Wrocław	PD	mKuran / OtwarteDane
MZK w Gorzowie Wielkopolskim	Source / authority specific	przyjazdy.pl
Szybka Kolej Miejska	Source / authority specific	NAP PL / przyjazdy.pl
Warszawska Kolej Dojazdowa	CC0	mKuran
Vbb.de (local)	CC BY 4.0	Transitland / NAP DE
Vbb.de (rail)	CC BY 4.0	Transitland / NAP DE
Koleje Małopolskie SKA	NAP/CC BY 4.0	NAP PL
Koleje Dolnośląskie	CC0	mKuran
Koleje Mazowieckie	Source / authority specific	mKuran
Koleje Wielkopolskie	Source / authority specific	przyjazdy.pl
Łódzka Kolej Aglomeracyjna	NAP	NAP PL
Koleje Śląskie	NAP	NAP PL
PKP IC	CC0 + Odbl	mKuran
Polregio	CC0	mKuran
nvbw.de	Source / authority specific	Transitland
Železničná spoločnosť Slovensko	CC0	Transitland
Flixbus-EU	ODbL	Transitland
peatus.ee	Source / authority specific	NAP EE
visimarsrutai.lt	CC BY 4.0	NAP LT

*NAP - not explicitly indicated, but available on the NAP PL portal, which consider such data as public domain

Of the 18 sources rejected, half were outdated, including the timetables for the localities of Bielawa, Krosno, Nowy Sącz, Płock, Przemyśl and Wieliczka. In the remaining cases, the acquired data sets were duplicates of information contained in the 48 analysed sets. This usually involved the repetition of timetable information on cross-border transport in different international sources or the acquisition of more than one source for a specific carrier or transport authority. At the same time, the content of the duplicate sets was not always identical. This situation occurred, for example, in the case of *ZDMiKP Bydgoszcz* or *Warszawski Transport Publiczny*.

The final dataset included information on the operation of PT in 16 of the 18 provincial capital cities (except for Opole and Zielona Góra), as well as information from most of the main railway operators operating in Poland (except *Arriva*). In the case of smaller towns, GTFSs were usually available for urban agglomeration towns (e.g. Kórnik, Wejherowo). However, there were exceptions in terms of GTFS availability in small, non-agglomeration towns (e.g. Ełk or Giżycko). Regional bus operators were very poorly represented - only *PKS Poznań*, bus services provided by *Koleje Małopolskie* and those provided in districts belonging to the NYSA Euroregion. The sources analysed included data from a total of 71 agencies, of which 68 were considered unique. The number of unique routes, after removing approximately 2.5% of duplicates, was estimated at 6447-6738. The datasets extracted were under different, sometimes dedicated, open licences or combinations thereof. The differences mainly concerned attribution expectations.

Analysis of the optional data indicated that information on the shapes of the routes was added relatively frequently, i.e. in 28 sources (58%). The other types of information were much less frequent. In the case of information on accessible transfers, this was the case in seven sources (15%), and only four (8%) referred to fares. Information related to accessibility for people with disabilities was also not very frequent. Only 14 sources (29%) provided basic information on wheelchair accessibility, of which only two (*Warszawski Transport Publiczny* and *Warszawska Kolej Dojazdowa*) contained both information on the accessibility of stops and individual trips. Not a single source analysed contained advanced accessibility data for the territory of Poland. It should be noted, however, that GTFS files downloaded from international repositories were adjusted only to the trips passing through the territory of Poland and using stops located in Poland, and to that extent, they were evaluated in Table 3. However, some of these sources contained data in pathways and levels files outside Poland.

The number of all stops located in Poland amounted to 49,150, of which 48,247 (98%) were active. Comparing this to the merged OSM+BDOT10k database, which contains less than 200,000 stops, the coverage of open PT information in Poland can be estimated at 25%. The frequency was determined for 35044 aggregated nodes. 1015 nodes were omitted, as they did not register a single journey on the analysed day. The highest median frequency was found for tram transport in Cracow - 298 trips/day. In other cities, one source contained timetables for both the tram and bus subsystems at the same time, so the latter had the effect of lowering the median. The highest daily frequency in the analysed set was at the *Rondo Rataje* junction in Poznań (which also contains a bus station). Practically every vehicle of more than 20 lines - plus other lines departing from and arriving at the depot through this interchange - stops at least twice at this junction, The neighbouring *Kórnicka* interchange was partially closed at the time of the analyses, redirecting some traffic to *Rondo Rataje*. Hence, the daily frequency was 2377. On the other hand, the lowest values were associated with trans-European bus services – one or two trips/day. It is worth noting here that the availability of individual categories of carriers affected the result obtained within the local government unit (municipality) under analysis, hence its representation in such a cross-section was abandoned.

In the case of the border with Lithuania, there were ca. 20 trips per day (i.e. ca. 0.39 trips per 1 km of the border), with Ukraine and Slovakia ca. 40 trips (0.08 trips/km), with the Czech Republic - 120 (0.15 trips/km), and with Germany - 490 (1.05 trips/km), including 18 crossing the border twice near the *Krzewina Zgorzelecka* railway stop. Due to the war situation in Ukraine and the associated restrictions, no regular trips were recorded between Poland and Russia and Belarus.

Data analysis by voivodeship (see Table 5, Fig. 1) indicated that most open data was available for the Śląskie Voivodeship. This voivodeship was characterised by the occurrence of 2 active stops per 1,000 inhabitants and more than 50% of the built-up area was within the range of stops. This translated into the lowest percentage of municipalities without access to public transport in the country. Transport information in this province was supplied by 8 different sources. This is a smaller number than in the case of the Małopolskie and Mazowieckie Voivodeships - 10 sources each. However, this was compensated for by the large number of stops included in the GTFS for the GZM (>7000). Noteworthy is the fact that the area of the Śląskie Voivodeship itself is smaller than that of the Mazowieckie Voivodeship.

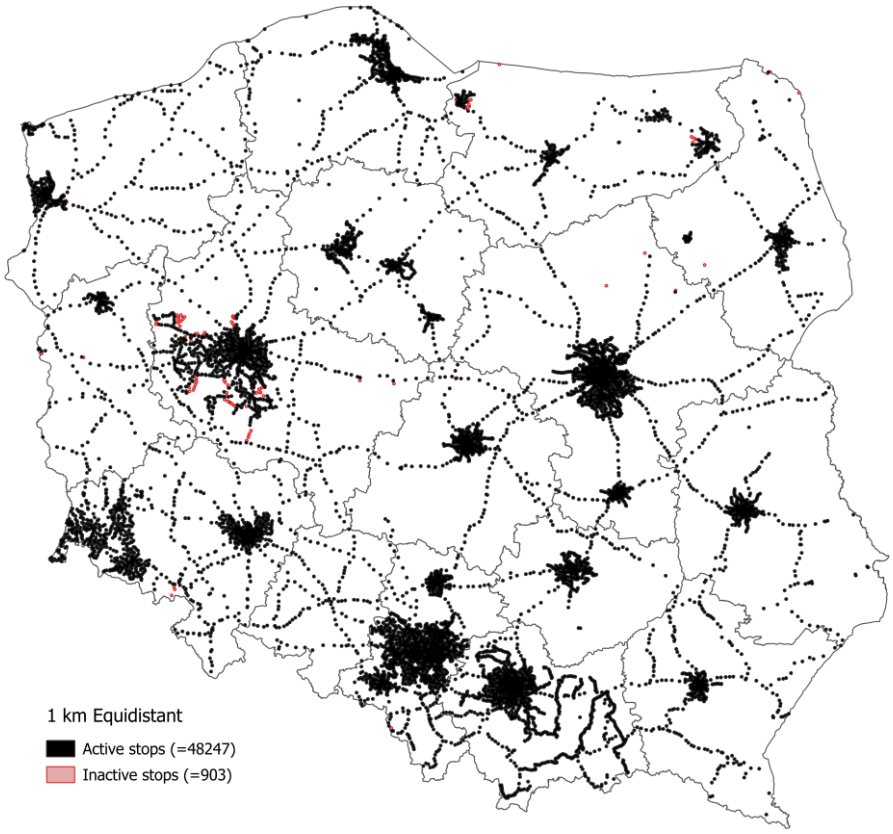

Fig. 1. 1 km Equidistant from stops as presented in open sources

Table 5. Summary of open data availability in the voivodeships

Voivodeship	No. of sources	Active stops / 1000 inh.	% of build-up areas within 1 km from the active stop	% gminas without access to PT [↑]
Śląskie	8	2,0	54,8	26,4
Dolnośląskie	9	1,4	44,7	26,6
Małopolskie	10	1,6	41,5	31,3
Opolskie	3	0,2	19,1	32,4
Zachodniopomorskie	8	1,1	35,2	35,4
Lubuskie	9	0,7	26,8	35,4
Pomorskie	8	1,4	46,7	38,2
Wielkopolskie	9	1,2	41,2	40,3
Podkarpackie	6	0,5	22,0	51,9
Warmińsko-mazurskie	9	1,0	35,6	53,4
Mazowieckie	10	1,5	45,4	56,7
Podlaskie	8	1,2	31,5	58,5
Łódzkie	7	1,0	33,0	59,3
Świętokrzyskie	7	1,2	26,2	62,8
Kujawsko-pomorskie	8	1,1	40,2	65,3
Lubelskie	5	0,7	20,0	67,1
Poland	48	1,3	35,2	47,4

The lowest number of available sources was in the Opolskie Voivodeship. These were GTFS of the rail carriers POLREGIO and PKP IC, as well as the international carrier Flixbus. These sources were also the only ones showing stops in all 16 voivodeships. It should be noted that despite the low availability of sources, the percentage of municipalities without access to public transport was lower in the Opolskie voivodeship than the national average - 32.4% vs. 47.4%.

In the southwestern part of the Lower Silesian Voivodship, a lot of information on the functioning of regional transport was available. This availability applies to districts belonging to the NYSA Euroregion, which provides, for example, an offer of a ticket valid in border regions in Germany and the Czech Republic. Interestingly, this data was not available from Polish sources but was obtained from a German *Öffentlicher Nahverkehr*.

PROPRIETARY DATA

An assessment of commercial providers in terms of the declared number of public transport entities served indicated that the two largest datasets in this respect are *AutobusowyRozkladJazdy* (>1300 entities after filtering out duplicates and entries suggesting termination of activity; the remaining entities included representatives of different transport categories, e.g. bus and minibus, local and interregional transport) and *ePodróżnik* (>800 entities). At the same time, these sets appear to be at least partly complementary. According to *Autobusowy RozkladJazd*y, the Małopolskie Voivodeship was the voivodeship in which the fewest number of transport operators declared their registered office (15 entities). This voivodeship was also the second most represented in the other supplier (>100 entities). The next largest providers were *TravelTime* (>250 entities in the country) and *KiedyPrzyjedzie* (~90 entities). It is worth noting here that the datasets provided by the smaller providers did not constitute a mere subset of the information provided by the largest ones.

The results of the analysis from a geographical coverage perspective (Fig. 2) show that there was no single source that covered all the data. The capital cities of the largest agglomerations were served by around 50% of providers. In contrast, there were only single providers operating outside the largest cities, and 83% of municipalities were outside the claimed coverage of any of the providers. This distribution was uneven - the best situation in this respect was in Śląskie Voivodeship (41% of municipalities were "PT white spots") and the worst in eastern provinces - Podkarpackie, Podlaskie, Świętokrzyskie and Lubelskie - 90% or more such spots in each (see Tab.6).

Table 6. Summary of availability of proprietary data by voivodeship

Voivodeship	% gminas without access to PT [↑]	Difference with Open Data [p.p.]	Difference with Open Data [p.p.] – local transport only (local+regional bus)
Śląskie	41,3	-15,1	15,6
Dolnośląskie	75,0	-21,6	12,9
Małopolskie	79,9	-53,3	+14,8 (-5,9)
Opolskie	80,5	-45,1	+8,5 (+6,1)
Zachodniopomorskie	80,5	-45,1	10,7
Lubuskie	83,1	-50,7	16,9
Pomorskie	83,3	-18,0	5,6
Wielkopolskie	83,6	-43,3	+7,1 (-4,0)
Podkarpackie	83,7	-45,5	2,5
Warmińsko-mazurskie	86,6	-29,9	-1,6
Mazowieckie	87,4	-56,1	+1,1 (-34,1)
Podlaskie	89,3	-30,0	2,8
Łódzkie	90,0	-38,1	4,4
Świętokrzyskie	90,7	-32,2	0,8
Kujawsko-pomorskie	91,2	-28,6	-2,0
Lubelskie	92,0	-24,9	2,8
Poland	82,7	-35,3	+5,6 (+0,5)

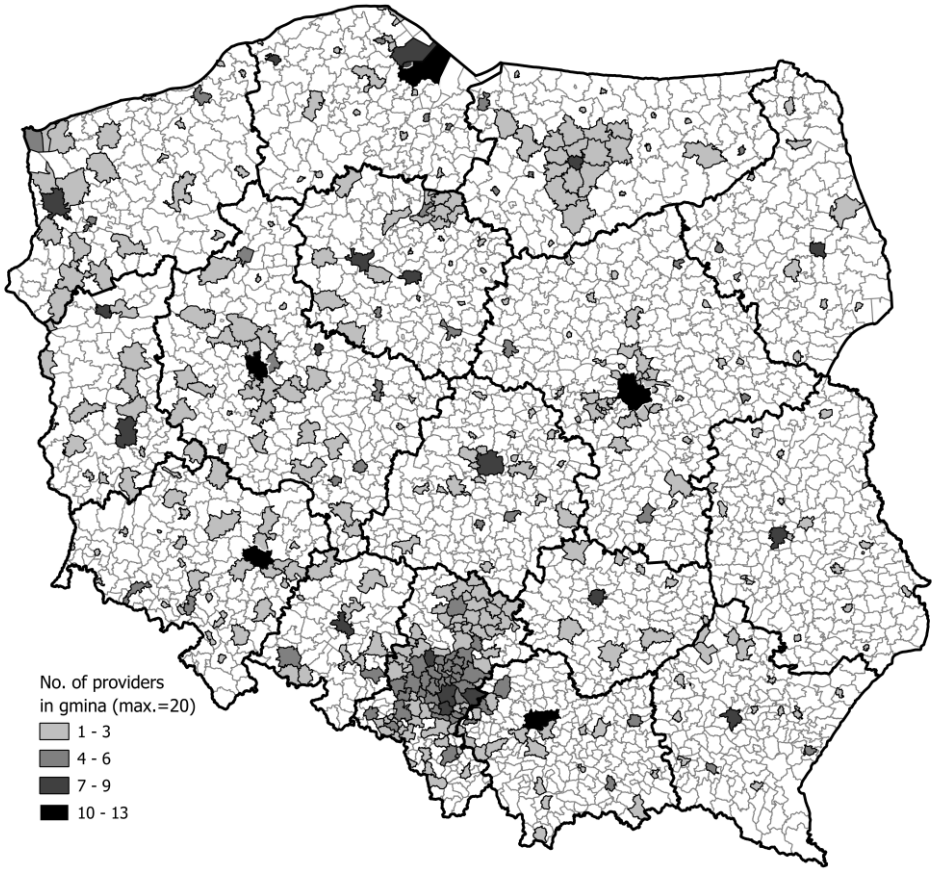

Fig. 2. Availability of commercial information providers regarding PT in gminas (**max.=20**)

4. RESULTS

OPEN DATA

The coverage of open information on PT was estimated at 25%. It is worth noting, however, that a uniform digital database of stops, comparable to e.g. the British *NaPTan*[12] is not available in Poland. This results in uncertainty in both the numerator and denominator of this indicator. The non-existence of a uniform database means that the same stops in different GTFS sources (as well as in the BDOT10k and OSM databases) may have both different names and geographical coordinates. As a result, it was difficult to merge the sources and determine the number of unique stops, e.g. uncertainty about the actual number of stops that are 10 metres from each other. In the case of the GTFS, the lack of consolidation mainly concerns stops that are major railway and bus stations used by both local and international carriers.

On the other hand, considering that open sources were available for the most extensive agglomeration public transport systems, where the median frequency was higher, it can be assumed that the coverage of open digital data of a daily number of trips may be higher than 25% in Poland.

Regarding cross-border trips, their relatively high number between Poland and Germany seems to be a combination of the high level of digitisation and openness of PT information in Germany and the presence of twin cross-border towns that are connected by local transport. A high level of digitisation of timetable data is also noticeable in the Baltic States. It seems to be lower in the other neighbouring countries.

[12] https://www.data.gov.uk/dataset/ff93ffc1-6656-47d8-9155-85ea0b8f2251/national-public-transport-access-nodes-naptan (accessed 2023.05.23)

The assessment of the so-called "PT white spots" at the level of municipalities seems to be too imprecise, as can be seen in the Opolskie Voivodeship, where one source (POLREGIO) containing 117 stops provided at least one stop in more than 2/3 of municipalities. At the same time, the range of these stops covered less than 20% of the built-up area in the voivodeship.

Ultimately, it should be concluded that it is not only the lack of open digital data for a large part of Poland that is of concern, but also the occurrence of sites where data were available from more sources, but these data were not exactly the same. Analysis of these sources suggests that this may have been the result of differences in data preparation. For example, one source may have been prepared by a third party using data scraping techniques on timetables provided by the PT authority in html/pdf format. In contrast, the other source may have been generated directly by the authority's IT system. Hence, it appears that the other source is of better quality. However, the problem was that updates to the other source were done manually, not necessarily together with updates to the html timetable. From the perspective of information consumers, the issue of assessing reliability arises. They must decide whether to trust an unofficial source, which has a longer and more error-prone data processing path but is updated automatically on a daily basis, or an official source, with a shorter data processing path but possibly outdated. Neither of these sources is necessarily considered reliable enough. It is important to note that the authors of the paper agree with the postulate by Lyons&Harman [31] that datasets should be managed by the organizations that produce the data. This increases the likelihood of accuracy and up-to-date information.

PROPRIETARY DATA

The proprietary data analysis suggests that in the case of major agglomerations (see Fig. 2), a passenger's use of a randomly selected commercial solution is quite likely to assist them in planning a journey. In the case of rural areas, however, they would need to be much more knowledgeable. This confirms the claims made in [32] that passenger information channels should also be promoted, alongside the promotion of public transport itself. This need is greater in rural areas than in large cities.

Furthermore, it should be noted that commercial providers quite rarely indicated all the localities for which they provided PT information services. Instead, they indicated, for example, only the capital city of the agglomeration, whereas data were available for all areas included in the agglomeration. On the other hand, those producers who reported more widely on the availability of data in agglomerations may have unconsciously omitted, the information regarding some of the connections organised in these areas by other carriers. Both approaches, therefore, appear to be problematic from the perspective of how easy or difficult it is for passengers to search for PT information outside the agglomeration centres. Nevertheless, it should be noted that some commercial providers, such as *TravelTime* or *Transitland*, visualise the actual information availability ranges in their datasets. They use isochrones around supported stops or actual route shapes for this purpose. This can be considered an example of best practice. From the perspective of this work, however, this information could not be used unless payment was made or it would have been extremely time-consuming due to restrictions on access to APIs in free plans.

In addition, the higher share of municipalities without access to public transport in commercial solutions in the eastern Polish voivodeships may not be solely the result of poorer accessibility in these voivodeships. An important role may also be played here by a combination of the previously mentioned inaccurate information on the extent of accessibility reported by IT providers, as well as the assumptions of the survey, including the lack of specification of interregional carriers and the limited scope of the survey of the *Google Maps* planner. The result may be also influenced by the very structure of gminas in the voivodeships - there are more rural gminas in eastern Poland than in the west of the country.

Note also that when analysing *Google Maps*, the authors observed the presence of timetable data not only provided by large public transport operators but also by smaller carriers such as *Markobus* and *Matmich-Bus*. Given that *Google Maps* uses the GTFS standard, this suggests that the use of this standard does not necessarily constitute an undue barrier for smaller PT operators.

Finally, the analyses for commercial sources were based on supplier declarations, which were not verified in detail, as this would often require the purchase of a database which was not part of this study. Hence, despite the removal of questionable records, which was particularly the case for *AutobusowyRozkladJazdy* and *TravelTime*, the numbers of entities indicated in the paper constitute an upper estimate. In addition, there are other carrier datasets available for Poland, ranging from general databases of business entities to databases under research curation, e.g. [33]. Their detailed analysis, however, did not constitute the subject of this study.

OPEN VS PROPRIETARY DATA

An analysis of commercial solutions suggests that at least some of them (e.g. *jedzie, kiedybus, czynaczas* and *gdziejestautobus*) appear to use open real-time data provided by PT authorities. This confirms indications in the literature (see introductory chapter) that open transport data supports the development of different types of applications. On the other hand, it should be noted that the solutions indicated above are limited in scope to only selected major Polish cities that have made their data sets open.

A comparison of data availability indicated that in terms of the number of operators and carriers included, proprietary data is far more complete. The largest commercial providers in this respect offer access to hundreds of entities. The opposite appears to be the case when examining data availability by municipality (see Tab.6). However, this is probably related to the assumptions of the survey and the lack of specification of smaller localities in the declarations of commercial providers. The inclusion of only local transport datasets on the open data side suggests similar availability in both datasets, with the exception of the Dolnośląskie, Lubuskie, Opolskie, Śląskie and Zachodniopomorskie voivodeships. But with open data being available in municipalities surrounding agglomeration capitals, and commercial data tending to be available in smaller towns. In addition, the inclusion of regional bus services (i.e. *PKS Poznań, Koleje Małopolskie ALD* and *Euroregion NYSA*) causes a large change in the results in the voivodeships covered by these datasets. Some commercial providers also make data available for this category of transport service, but from the perspective of the authors of this study, their exact coverage was difficult to assess. From the passenger perspective, this is especially problematic in situations where the journey involves interchanging between carriers whose schedules have been made available by different providers. With open data, the problem of combining different datasets also occurs, however to a lesser extent. The locations and names of stops have not been standardised in Poland in a single database, but the uniform, open GTFS standard makes it at least relatively easy to assess whether specific stops are located within a distance allowing the passengers to transfer.

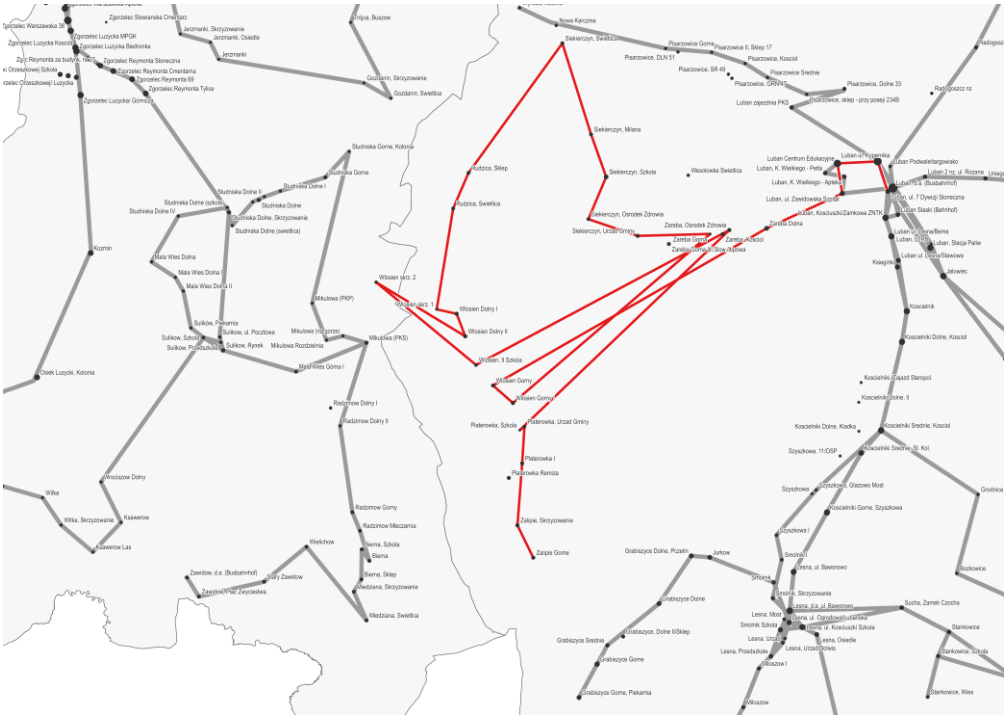

Fig. 3. A screenshot of the QGIS program showing the routes of transport lines in the Polish part of the Euroregion NYSA from the GTFS source "Öffentlicher Nahverkehr DE" (downloaded on 2023.03.15). **The red colour indicates the line which needs to be verified due to its unusual routing**

Of the abovementioned examples, the *NYSA* Euroregion seems to be the most striking illustration of the fact that the availability of open data does not necessarily translate into the availability in commercial solutions. However, the research carried out in this thesis does not allow for a conclusive answer as to the reasons behind this. One fairly obvious hypothesis here is the possibility of market failure - from the perspective of commercial providers, rural areas may not be attractive enough to be included in their offer. However, another hypothesis is that this market has not yet had the opportunity to emerge in Poland due to the presence of barriers resulting in a lack of knowledge of the existence of these data (in the case of the NYSA Euroregion, the data was only available in German repositories) or their insufficient reliability and quality from a business perspective. Some data repositories explicitly indicated that they were not responsible for the data provided. In addition, analysis of the data for the NYSA Euroregion suggests that there may be errors in the data, e.g. incorrect routing of lines (see Fig. 3).

CONCLUSIONS

The study suggests that despite the initial stage of digitisation of PT information (compared to e.g. Germany or the Baltic countries), in Poland such data can be found in an open model. Further research work in this area, however, requires both an answer to the question of why some datasets are no longer open (only historical sets are available) and what hinders their further opening, whether by PT authorities and carriers for whom timetables are available in commercial sources or by those who have not yet started the process of digitisation. The review also suggests that commercial solutions are quite well developed in Poland, also in the area that has not been analysed in detail, therefore it would be possible to plan international and interregional routes. In the case of some commercial solutions, development trends towards the MaaS model are also discernible. Some of the applications include the functionality for making fare payments. Several solutions that combine urban and regional transport (e.g. *jakdojade)* or urban transport and micro-mobility services (e.g. *VOOOM*) are also being developed. These are potentially interesting areas for further research work, particularly in assessing to what extent the level of development of open data influences the development of MaaS. This work should also focus on answering the question of why commercial solution providers do not always reach for available open data sets. This is particularly important given that there is now a demand in the Polish political space for a single travel planner for the whole country. The analyses conducted in this paper suggest that the market failure is not necessarily the reason for the lack of use of open data in non-urban areas. It cannot be ruled out that this market has not had the opportunity to develop in Poland due to problems with the availability and broadly understood quality of open sources. In addition, the question of whether it makes sense to implement such a planner also requires other types of analysis, such as cost analysis. It should be noted that in the UK, such a solution was created as early as in 2004 (Transport Direct Portal), but was abandoned in 2014 precisely because of the development of other solutions[13]. Ultimately, it should be noted that the analysis carried out in this article relates to a rather dynamically changing market. Both the number and spatial scope of open data and the number and scope of commercial solutions are changing. Hence, this research would be worth repeating in the future.

ABBREVIATIONS

1. **PT** – Public transport.

ZASIĘG CYFROWEJ INFORMACJI O TRANSPORCIE PUBLICZNYM W POLSCE

Informacja ma duże znaczenie w systemach publicznego transportu zbiorowego (ptz) wpływając na jego atrakcyjność. W ostatnich latach pojawił się trend cyfryzacji i otwierania danych związanych z funkcjonowaniem ptz. Jednak proces ten przebiega w różnym tempie w różnych krajach. W niniejszej pracy autorzy przeanalizowali dostępność cyfrowej informacji o ptz w Polsce. W tym celu przeanalizowano 16 repozytoriów otwartych danych oraz 22 rozwiązania komercyjne. W efekcie pozyskano 66 otwartych źródeł danych o publicznym transporcie zbiorowym w formacie GTFS, z czego 48 było unikalnych i aktualnych. Dane zawierały informacje rozkładowe dla 68 unikalnych operatorów transportu i blisko 50 tys. przystanków, które obejmowały swoim zasięgiem 35% powierzchni zabudowy w Polsce. Zdecydowanie rzadziej dostępne były informacje dodatkowe, np. o taryfach. Analiza rozwiązań komercyjnych wskazała, że pod względem liczby uwzględnionych przewoźników, rozwiązania te zawierają więcej danych od zbiorów otwartych. Analiza pod względem zasięgu geograficznego była mniej konkluzywna. Dodatkowo poza największymi miastami funkcjonowała zazwyczaj niewielka liczba rozwiązań komercyjnych. Powoduje to, że planowanie podróży z ich wykorzystaniem jest na obszarach wiejskich znacznie utrudnione, a pasażer musi mieć dobrą wiedzę o tym, które rozwiązanie wybrać w danym miejscu.

Słowa kluczowe: publiczny transport zbiorowy, informacja, otwarte dane, dane komercyjne, Polska.

[13] https://web.archive.org/web/20140912041722/http://www.transportdirect.info/Web2/downloads/closedownletter.pdf (accessed 2023.05.25)

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