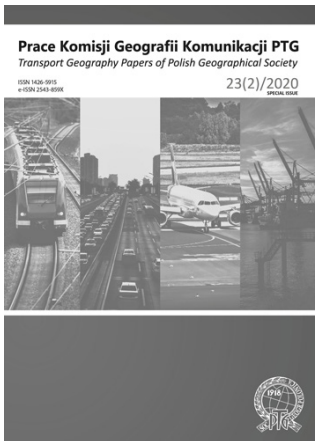

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COVID-19 LOCKDOWN IN POLAND – CHANGES IN REGIONAL AND LOCAL MOBILITY PATTERNS BASED ON GOOGLE MAPS DATA

Niefarmaceutyczne interwencje w związku z COVID-19 w Polsce – zmiany w regionalnych i lokalnych wzorcach mobilności na podstawie danych Google Maps

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Abstract: As no effective treatment or vaccine have yet been developed, the only way to prevent the spread of SARS-Cov-2 is to introduce social distancing measures. Scientific discussion regarding their actual effectiveness and socio-economic consequences has only just begun. Both declining mobility and changes in mobility patterns are obvious effects of social distancing. The main objective of this article is to present spatial diversity of changes in regional and local mobility in Poland with the use of data gathered and provided by Google LCC. As for the regional dimension, the mobility has declined steadily in most of the analysed areas. The regional changes were more visible only in the case of the following categories of areas: grocery & pharmacy and parks. The initial correlation analysis has shown that distribution of those changes more or less reflects spatial voting patterns. Both historical and cultural factors may explain such results, including ingrained habits, collective attitudes towards politics and group values. In the local context, illustrated by the analysis of changes in travel time from housing areas in Gdańsk, Gdynia and Sopot to the business and science centre in Gdańsk-Oliwa, a noticeable yet spatially diversified decrease in drive time (by private car) has been observed. The most significant reduction in travel time was recorded in peripheral areas accessible by high-speed roads which are normally jammed during peak hours. The mobility constraints have led to highly reduced traffic congestion, and consequently, shortened the travel time.

Keywords: COVID-19, Google Maps data, lockdown, mobility patterns, Poland

Introduction

When developing the concept of network society, M. Castells (2004) emphasized the role of information in society as well as in the process of increasing competitiveness of companies based on skilful use of resources provided by various networks. The issue of migration, being part and parcel of the network society development, was not prioritised by the author. However, J. Urry (2016:4) points out that "movement became a significant in the contemporary world – indeed the freedom of movement, as represented in popular media, politics and the public sphere, is the ideology and utopia of the twenty-first century. The UN and the EU both enshrine rights to movement in their constitutions." The above-cited author mentions five aspects of mobility. While three of them have truly intangible nature (imaginative, virtual and communicative travels) and can be performed using IT infrastructure, the remaining two – "physical movement of objects as well as corporeal travel of people ranging from commuting to one-in-a-lifetime exile" (Urry, 2016: 4) are based on highly developed transport infrastructure. The technical progress and various organisational improvements in transport systems have led to a rapid growth in mobility. At the beginning of the 19th century, the average American covered a distance of 50 km a day on foot, horseback or by carriage. Nowadays, the distance has not changed but it is covered by car or plane (Buchanan, 2002 za Urry, 2016). Obviously, the USA is an extreme case, yet the connection between technological development and the increased mobility of people is clearly visible and can be observed in most societies. At the same time, the so-called modern society is a society at risk – ecological, healthy, IT and social (Beck, Scott & Brian, 1992). The unprecedented scale and consequences of SARS-CoV-2 spreading during the first few months of 2020 may suggest that this is a black swan event – an unexpected event of large magnitude and consequence (Taleb, 2007). Nonetheless, various researches were assessing the likelihood of pandemics in the past as well as they were giving numerous warnings of such a danger (Chneg et al., 2007).

The main objective of this article is an attempt to answer the question to what extent the social distancing measures and mobility restrictions (lockdown) introduced in Poland have affected daily migration patterns. The analysis aimed at answering this research question covered two spatial dimensions – local and regional (NUTS 2) and several types of travels (tab. 1). The local dimension of the study concerned changes in travel time (by car) from residential districts located in three neighbouring cities to the largest business and science centre in the area. The analysis covered the area of Gdańsk, Gdynia and Sopot which altogether form the core of the urban area classified as Weak MEGA according to FUA& MEGA classification by ESPON (Polycentric Territorial Structures…, 2016). The basic research period was 6 weeks, from the mid-February to the end of March 2020.

The structure of the article reflects the research procedure. Firstly, a short review of literature on mobility restrictions and their impact on the spread of the coronavirus (SARS-CoV-2) was done. Then, research methods, data sources and subsequent stages of implementing social distancing measures in Poland were described. In the following sections the results were elaborated in the local and regional context. The article ends with a brief discussion summarising the results and conclusions.

1. Scientific background

Most scientific publications concerning relations between epidemics caused by infectious diseases and mobility focus on two basic and interrelated issues. The first one – epidemic – focuses on the role of human mobility in spreading of pathogens. The second – economic – regards the effects of epidemics on the transport sector. Obviously, in the case of SARS-CoV-2 all the results are preliminary and they mainly regard spread of the virus in China.

As for the epidemic stream of research, the authors usually study effectiveness of mobility restrictions and bans. Their results are inconclusive. On the one hand, they suggest that social distancing measures are effective. Early implementation of restrictions such as: banning interurban travels, suspension of public transport, closing commercial facilities and other social distancing measures helped in decreasing the pace of the coronavirus spread (Kreamer et al., 2020, Lau et al., 2020, Tian et al., 2020). On the other, Chinazzi et al. (2020) claim that in China reducing the number of travels, especially domestic ones, with no additional restrictions only postponed the expansion of the virus by 3-5 days. This measure was more effective in the international context. However, travel restrictions combined with considerably reduced (by approx. 50%) personal contacts between members of the same community were much more effective. Wilder-Smith et al. (2020) compared SARS-CoV-1 and the 2003 epidemic as well as the methods used to fight it at that time with the known features of SARS-CoV-2. The comparison indicates that the previously used methods may not be fully effective in the case of SARS-CoV-2 and that it may be necessary to shift from containment to mitigation.

The economic studies focus on global macroeconomic consequences of the pandemic. According to W. McKibbin and R. Fernando (2020), all modes of transport are highly vulnerable to negative consequences of the pandemic, no matter the scenario of further changes. Land, sea and air transport are key elements of supply chains which are being disrupted by unstable operation of industrial plants and transport hubs (Ivanov, 2020). The issue of potential impact of the pandemic on public passenger transport systems in urban areas has not been analysed yet. However, there are two basic reasons why this problem seems to be important. Firstly, implementation of social distancing measures results in decreased ticket sales, what constitute particularly important revenues of transport companies. Secondly, spread of the virus in closed spaces, like inside a bus/tram passenger compartment, is much quicker and many people may be reluctant to use means of public transport even when the pandemic is over.

2. Data sources and research methods

Spreading of SARS-CoV-2 in Poland began much later than in China. That is why it is definitely too early to draw any conclusions based on the Chinese scenario. Nonetheless, it is possible to make a preliminary estimate of effectiveness of the administrative measures and how they have affected daily migration. This cane be easily done with the use of location data collected from smartphone users. Such data is collected and processed by companies providing operating systems installed in smartphones. Google LLC and Apple Inc. are two main operating systems providers both worldwide and in Poland. Yet, in Poland almost 94% (March 2020) of smartphones have Android system installed (Mobile Operating System…, 2020). Location data along with other information on mobile phone users have a tremendous market value and they are not easily accessible. Open access databases are usually in a form which does not allow to use them in a commercial way. In order to get more detailed information, a fee must be paid. At the end of March 2020, Google LLC published a set of reports entitled COVID-19 Community Mobility Report (2020). The reports cover the period from 16th February to 29th of March 2020. The data on changes in mobility is expressed as percentages. Changes for each day are compared to a baseline value for that day of the week. The baseline is the median value, for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020. The authors divided the data into six categories (tab. 1) that are useful to social distancing efforts as well as access to essential services.

Tab. 1. Categories of location used by Google LLC for the mobility analysis.

Category	Places included in the category
Retail & recreation	Restaurants, cafes, shopping centres, theme parks, museums, libraries, and movie theatres
Grocery & pharmacy	Grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens
Transit stations	Public transport hubs such as subway, bus, and train stations
Workplaces	Places of work
Residential	Places of residence

Source: COVID-19 Community Mobility Report (2020).

Despite many obvious advantages (high population coverage, high spatial accuracy, short time of data gathering and processing – 2-3 days), the presented method has also some drawbacks. Firstly, the analysis is limited to the busiest places in a given region, as there have to be enough cases to provide credibility of the analysis. Moreover, the user settings (the Location History), connectivity as well as GPS signal quality are important factors affecting the results.

In the case Poland, not only general data for the whole country was published, but also some regional data (NUTS 2). As for the location categories, it is worth mentioning that the actual places included in them are usually located unevenly within regions. They are the nodes of the space of flows, as defined by M. Castells (2004), scaled-down to the microscale of single places saved in the Location History of the smartphone users. Almost all listed categories are usually located in urban areas – understood not only in the administrative context, but also in spatial, social and economic dimensions. However, the spatial differences in the intensity of urbanization of Polish regions are noticeable, at the same time not so great to result in much geographical generalization bias (Domański, 2004) of interregional comparisons of mobility changes. Moreover, the categories reflect the spatial-functional structure of Polish regions quite adequately. The only inconsistency has been detected for national parks as they are within the "Parks" category including mainly places located in urban areas (e.g. public gardens, dog parks) whereas in Poland national parks are usually located in rural areas.

As for the local dimension of the study, the analysis covered 59 housing estates located in Gdynia, Gdańsk and Sopot from which people commute to the selected business and science centre. Using data provided by Urban Atlas 2012 and OpenStreetMap (December 2019), for each housing estate a separate centroid was determined. In the next step, routes connecting the centroids and the business and science in Gdańsk Oliwa were marked using the ORS Tools plugin for QGIS with the Directions function on. Then, the routes were divided into 121 non-overlapping sections (fig. 1). Starting and finishing points of the sections were input data for the Distance Matrix API (google LLC). This service provides travel distance and time taken to reach a selected destination. This API returns the recommended route between origin and destination, consists of duration and distance values for each pair. The "real" travel time is calculated with the use of different algorithms and both historical and present data on traffic that has been collected by the service provider (Wiśniewski, 2016).

The analysis of changes in travel time between the set points was carried out in two rounds during weekdays – from Tuesday to Thursday during morning (6.00-10.00 a.m.) and afternoon (2.00-6.00 p.m.) peak hours. The first round took place on 25-27th February, the second on 24-26 March 2020. The measurements were taken every 5 minutes for all selected sections. Then, average travel time was calculated for all sections on the basis on 147 readings for each time period (morning and afternoon peak hours). Finally, the sections were merged to take the form of the initially delimited routes.

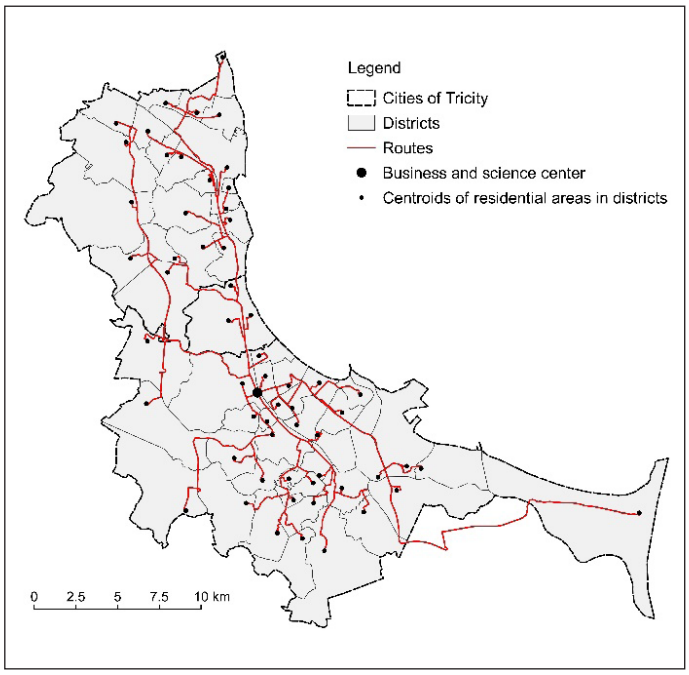

Fig. 1. Commute routes between residential areas of Gdańsk, Gdynia, Sopot and the business and science centre in Gdańsk Oliwa.

Source: own elaboration.

3. Data sources and research methods

The first case of a laboratory confirmed SARS-CoV-2 infection in Poland took place on 4th March, 2020 – one month later than the first European countries to cope with the virus. At the end of the research period, on 29th March, there were already 1863 confirmed cases in Poland (Mapa zarażeń koronawirusem…, 2020). The local transmission phase of SARS-CoV-2 in Poland was declared to the World Health organisation on 10th March. Four days later, in response to a rapidly growing number of infections, the Polish Government declared the state of emergency epidemic. As part of the country's effort to stop the spread of Coronavirus Poland reintroduced border controls, closed

some service facilities and introduced social distancing measures. Moreover, all schools in Poland were closed starting on 12th March. An official epidemic was declared on 20 March 2020. Four days later some further restrictions on people leaving their homes and on public gatherings were announced. Non-essential travel was prohibited, with the exception of travelling to work or home and the number of seats in buses, trams and other means of public transport was reduced (Rozporządzenie Ministra Zdrowia..., decline in the daily migration was observed between 9th and 15th March, that is before the first formal restrictions were introduced. Any further decline, if it was observed, was not that clearly visible. The only category that did not follow this scheme is the parks where a bit larger variability was observed. However, a significant decline in mobility was observed in places belonging to this category at the end of the analysed period (fig. 2).

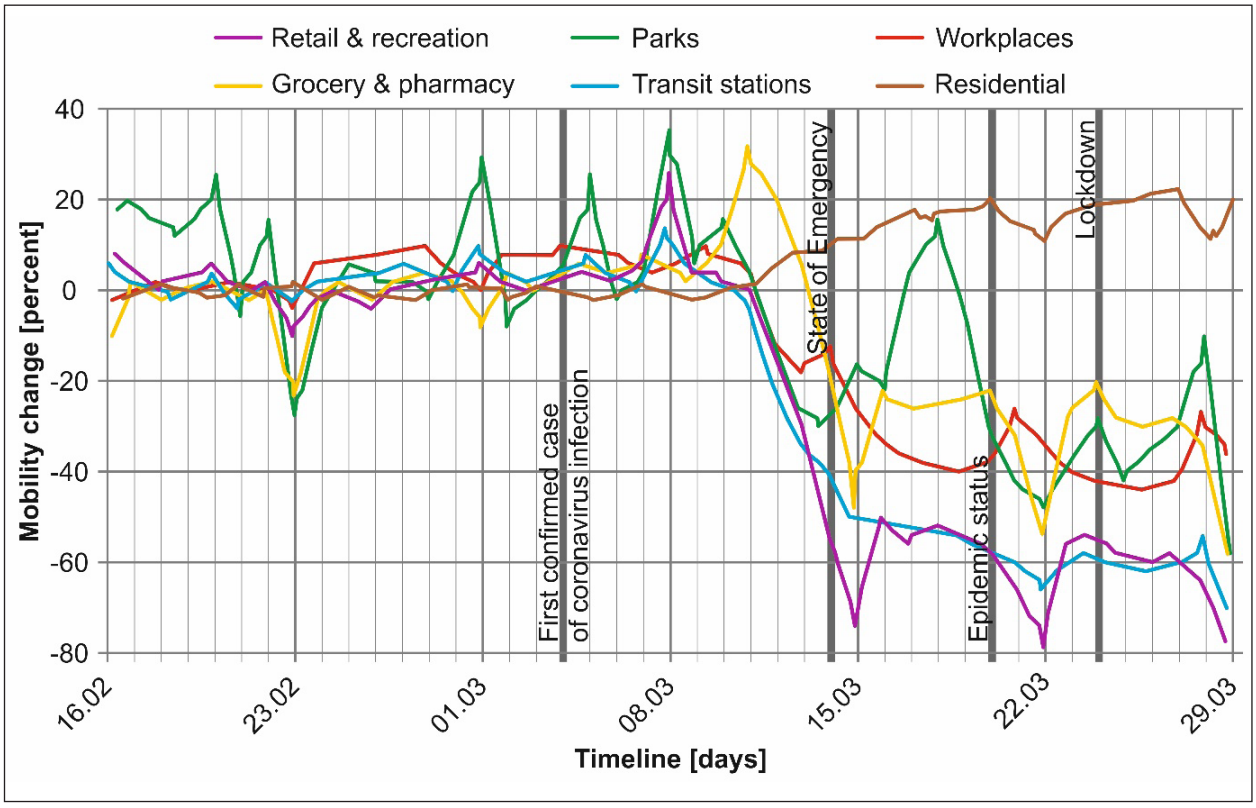

Fig. 2. Mobility changes in Poland from Feb 16 to Mar 29 (2020).

Source: own elaboration based on COVID-19 Community Mobility Report (2020).

2020). On 1st April the restrictions were strengthened, including closure of parks, boulevards and beaches. However, this period is not covered by this study.

An obvious response to all introduced restrictions was reduced daily mobility of people. A clearly visible reduction in mobility was observed in the whole Poland for 5 out of 6 categories of places analysed by Google LLC (2020) (fig. 2, tab. 2). The largest drop in mobility was observed in the retail & recreation and transit station categories (-78%) while the smallest one in the workplaces category (-36%). As for the residential areas, the mobility increased by 13% as some professionally active people stayed at home. What is actually interesting, is the fact that a rapid

4. Decrease in mobility – regional breakdown

Spatial diversification of the mobility changes resulting from both the implemented restrictions and the fear of infection itself is the most interesting issue for geographers, especially those keen on transport geography. However, for most of the analysed categories it was minimal (tab. 2) and it was a direct result of implementing precise and common restrictions. Only for the parks and grocery & pharmacy a higher level of spatial diversification was observed (tab. 2). In general, for both categories the decline in mobility was more visible in the western regions than in the eastern ones (fig. 3).

Tab. 2. Mobility changes in Polish regions (NUTS 2) from Feb 16 to Mar 29 (2020).

	Retail & recreation	Grocery & pharmacy	Parks	Transit stations	Workplaces	Residential
POLAND	**-78%**	**-59%**	**-59%**	**-78%**	**-36%**	**+13%**
Dolnośląskie	-82%	-65%	-71%	-77%	-38%	+13%
Kujawsko-Pomorskie	-79%	-63%	-73%	-78%	-33%	+12%
Lubelskie	-71%	-44%	-25%	-71%	-32%	+12%
Lubuskie	-77%	-65%	-55%	-72%	-37%	+12%
Łódzkie	-74%	-55%	-49%	-66%	-29%	+13%
Małopolskie	-84%	-65%	-69%	-78%	-41%	+14%
Mazowieckie	-77%	-54%	-60%	-70%	-35%	+13%
Opolskie	-79%	-62%	-55%	-72%	-37%	+12%
Podkarpackie	-71%	-46%	-11%	-71%	-36%	+13%
Podlaskie	-75%	-47%	-17%	-60%	-32%	+11%
Pomorskie	-82%	-64%	-78%	-78%	-38%	+14%
Śląskie	-77%	-58%	-50%	-65%	-35%	+13%
Świętokrzyskie	-74%	-44%	-26%	-67%	-34%	+12%
Warmińsko-Mazurskie	-77%	-60%	-63%	-73%	-35%	+11%
Wielkopolskie	-80%	-61%	-62%	-73%	-37%	+13%
Zachodniopomorskie	-80%	-66%	-76%	-69%	-39%	+12%

Source: COVID-19 Community Mobility Report (2020).

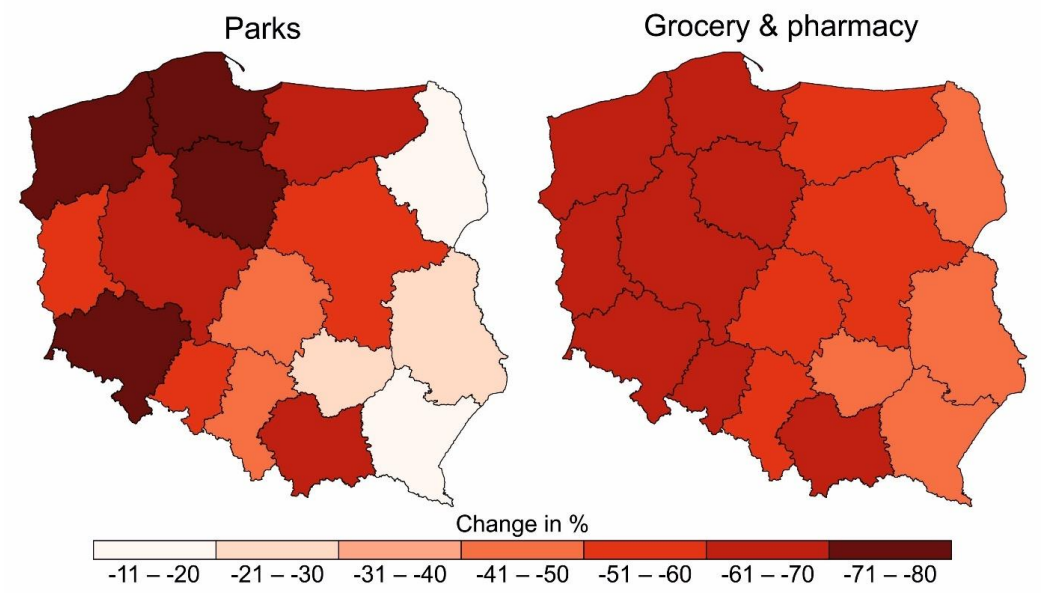

Fig. 3. Mobility changes in the park and grocery & pharmacy categories by Polish regions (NUTS 2).

Source: own elaboration based on COVID-19 Community Mobility Report (2020).

In the case of the grocery & pharmacy category, subsequently introduced restrictions were gradually reducing the number of customers allowed to stay in a facility at the same time (in relation to the number of checkouts). Yet, facilities of this type cannot be completely closed as they provide basic products. When it comes to the parks, those issues were not that clearly established during the whole analysed period. Therefore, in both cases there was a certain degree of freedom of movement and some changes in mobility were observed. In order to identify the reasons behind them an initial assessment of the variables interdependency (parks, grocery & pharmacy) was carried out. Table 3 presents explanatory variables used. It is worth emphasizing that the results are only preliminary – just signalling some directions

for more detailed further studies. The Pearson correlation coefficient was calculated and the analysis started with the most obvious potential reasons behind the mobility changes. The older the patient, the higher the risk of an acute course of COVID-19 disease. Such information has been widely spread. However, the dependency ratio, being one of the explanatory variables, is strongly correlated with any of the two explained variables. Similarly, neither the share of people with tertiary education (who are potentially more aware of the complex threat) nor the active citizenship indicators showed strong correlations with the above-mentioned variables.

A bit stronger correlations were observed between the social mobility reduction ratio for the analysed categories and the number of TV sets and computers in a household. It is possible that owners of those devices are more likely to stay at home, having a wide range of entertaining activities provided by television or the Internet. However, the highest correlations were observed in the case of voting preferences. The outcome of the parliamentary elections of 2019 was the base for the analysis. Although the correlations were relatively high, it cannot be stated that political views shape the willingness to self-limit. It seems that the historical and cultural factors are the common dominator. These issues constitute the main research interest of electoral geography and they were not covered by this study. W. Grabowski (2018) provides an elaborated and detailed analysis of the role of cultural and historical factors in the light of the parliamentary elections of 2015. The author emphasizes the significance of ingrained habits, collective attitudes towards politics and group values in shaping political views. The same factors may influence attitudes to living and working in pandemic conditions. In general, the correlations were stronger for the grocery & pharmacy category (tab. 3).

Tab. 3. Correlations (Pearson correlation coefficient) between the selected explanatory variables and the analysed categories: parks and grocery & pharmacy.

Explanatory variable	r for parks	r for grocery & pharmacy
dependency ratio	0.50*	0.27
share of people with tertiary education among the professionally active citizens	-0.07	0.10
participation in general elections (both Senat and Sejm)	0.00	-0.07
share of NGO activists	-0.13	0.06
share of votes cast for the Law and Justice Party in the parliamentary elections in 2019	0.58**	0.83***
share of votes cast for the Civic Coalition Party in the parliamentary elections in 2019	-0.61**	-0.81***
share of votes cast for the Alliance of Democratic Left Party in the parliamentary elections in 2019	-0.35	-0.73***
share of households accessing cable/satellite television	-0.25	-0.46***
share of households accessing the Internet	-0.11	-0.31
share of households with a TV set	-0.43*	-0.64***

*,**,*** mark the level of significance: 0.1, 0.05 and 0.01 respectively

Source: own elaboration based on COVID-19 Community Mobility Report (2020) and CSO local data bank (2020).

5. Decrease in mobility – intra-regional breakdown (Gdańsk-Gdynia-Sopot)

Though a negative change in mobility for the workplaces category was observed in Poland, it was the category with the minimal change. Still most of the professionally active people were commuting to their workplaces. However, the means of public transport were less preferable than private cars (Google LCC, 2020). The general drop in mobility resulted in a visible change in traffic. In the case of commuting to the business and science centre in Gdańsk Oliwa from Gdynia, Sopot and Gdańsk, the average travel time was shorter by 18%; by 15% during the morning peak and by 21% in the evening. The trend was clearly visible in the western districts of Gdańsk and Gdynia (fig. 4).

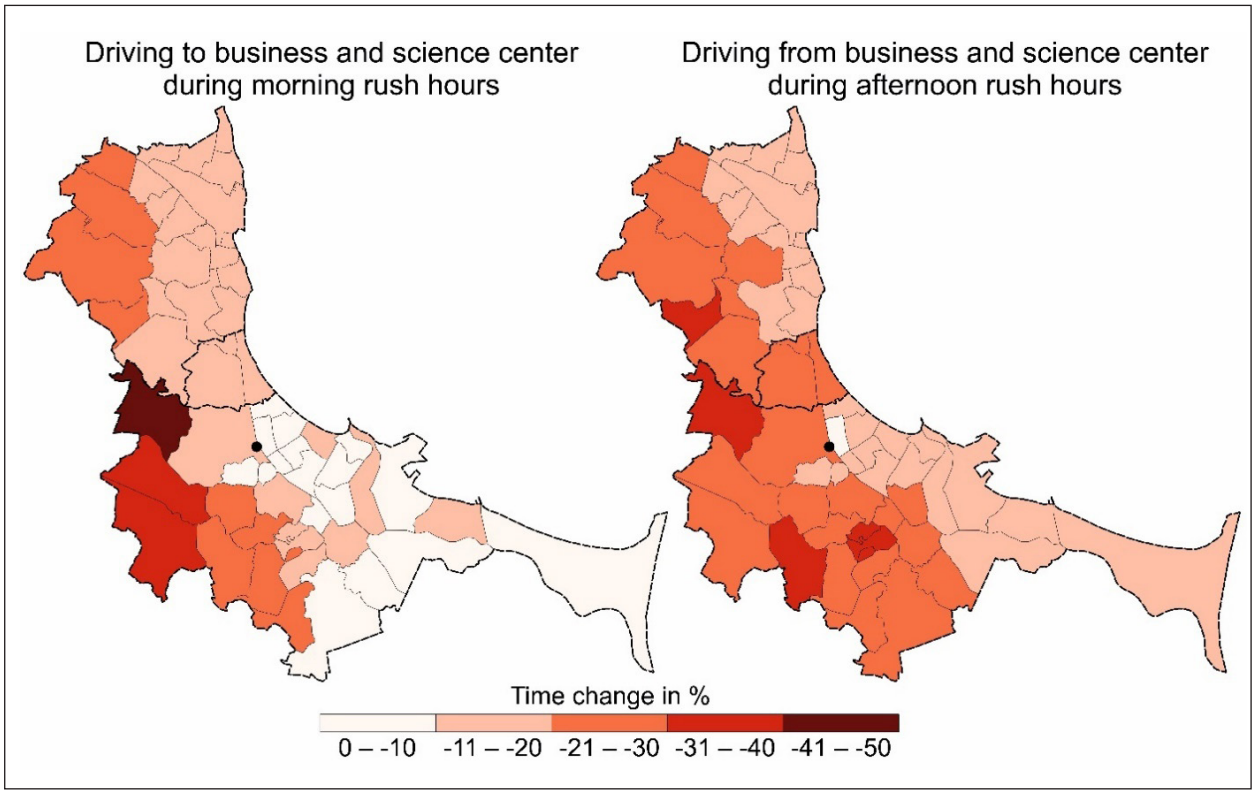

Fig. 4. Changes in travel time between selected districts in Gdańsk, Gdynia, Sopot and business and science center in Gdańsk Oliwa.

Source: own elaboration based on Google Maps data.

The above-mentioned areas were incorporated into the cities in the mid-1970's and after 1989, during the period of political transformation, they were undergoing intense urbanisation (Lorens, 2015). At that time the growth rate of motorisation became more rapid. Moreover, the private sector became the principal investor in housing construction, building some affordable houses and apartments in both peripheral districts and villages surrounding Tricity. However, the increasing number of residents was not accompanied by development of proper social and technical infrastructure. Development of the transport network was also hampered by environmental factors. The western districts of Gdańsk and Gdynia (called the "upper terrace") are separated from the central ones (the "lower terrace") by the upland edge covered with forest – Tricity Landscape Park, which is a protected area. This barrier makes it problematic to develop a road network of higher density. Technical parameters of the existing roads allow users to drive with the speed reaching 70km/h. However, the daily congestion is so high that the actual speed is much lower. The COVID-19 mobility restraints have made those roads more drivable. A clearly visible drop in the drive time between Gdańsk-Osowa (the highest reduction during the morning rush hours – fig. 4) and the business and science centre in Gdańsk-Oliwa is a perfect example here. The usual heavy traffic was almost non-observable during the pandemic (fig. 5).

As for the districts connected by inner-city roads, the decrease in the number of cars did not lowered the traffic density as there are too many junctions, traffic lights and the speed limit within the city is

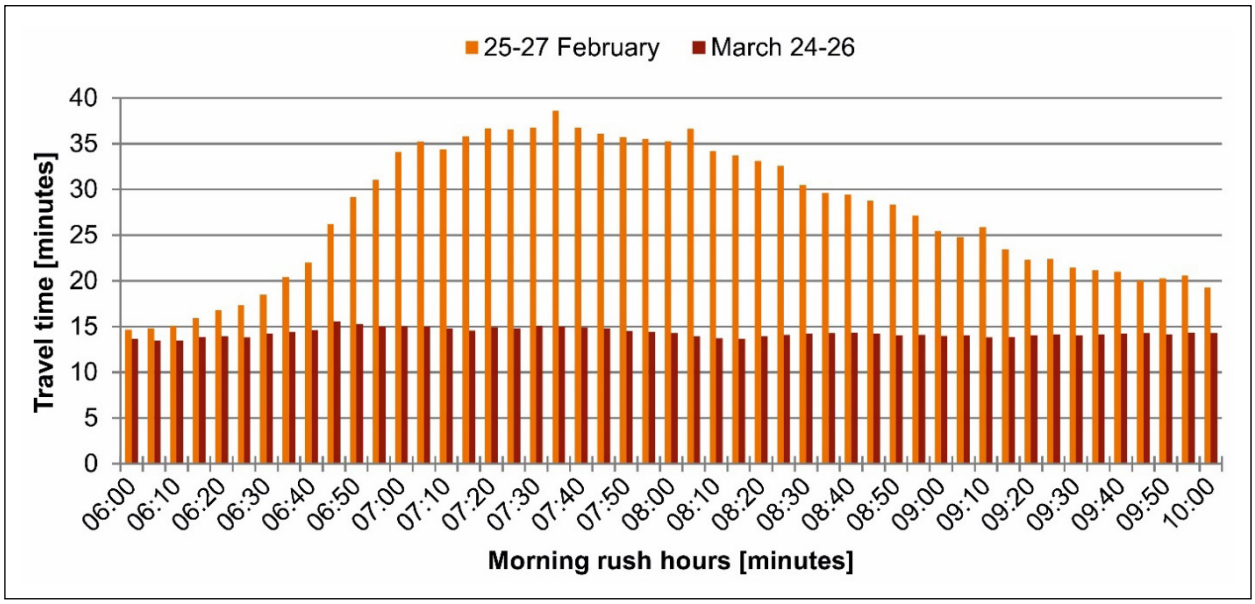

Fig. 5. Changes in travel time by car between Gdańsk-Osowa residential area and the business and science centre in Gdańsk-Oliwa in the period of 2020 Feb 25 to March 26.

Source: own elaboration based on Google Maps data.

much lower. Moreover, the central and eastern districts are not solely residential and they perform many other functions. Thus, the drop in the traffic density was not that significant.

Discussion and conclusions

The data provided by Google Maps (spatial big data) is a product of the data-driven business. Such data bases are created in a complex socio-technical system involving both a particular technology and its users. The usefulness of such data is determined by features typical for big data: volume, velocity (velocity of data generation but also to the access to data and the way data is processed and analysed) and variety (the diversity of information data may contain) (Boutin & Clemens, 2017). However, using big data involves numerous problems and challenges. The insufficient control of geodata collection and distribution processes (i.e. scarcity and poor quality of metadata and metadata systems), mentioned by Ivan et al. (2016) is one of them. The analysis of the Google LCC COVID-19 Community Mobility Report (2020) has confirmed it. The researchers were provided with very general explanation regarding the methods of data gathering and their limitations. Nonetheless, taking a considerably high level of data generalisation under consideration, and the fact that limitations of Google services are a well-known issue, the above-mentioned problem was not that acute. As for the analysis based on data provided by Google Maps API, one of the important problem is that there is little control over the route algorithm. This problem was already mentioned by Sz. Wiśniewski (2016) and F. Wang & Y. Xu (2011). In this study the routes were divided into smaller sections what resulted in higher control over the algorithm.

In the empirical dimension of the regional analysis, the most interesting results regard the attempt to explain the spatial diversity of social responses to the mobility restraints. The decrease in mobility regarding the parks and grocery & pharmacy categories was varied widely among the voivodships. This can be explained by the long lasting structures affecting different aspects of social life, including the spatial one (Sowa, 2012). Regional voting preferences along with a changing level of mobility freedom are their measurable manifestations. Most probably, the historical and cultural factors, which shape both voting preferences and attitudes towards the pandemic (Grabowski, 2018), are behind the similarity.

The local analysis revealed significant spatial diversity of changes in travel time (by car) between the selected districts of Gdańsk, Gdynia and Sopot to the business and science centre w Gdańsk Oliwa, that is the largest (according to the number of people working/studying there) facility of this type in the research area. The mobility restrictions were the most profitable for the citizens living in the peripheral districts connected by high-speed roads with high daily congestion. Therefore, the COVID-19 pandemic has consolidated the mobility patterns observed in large Polish cities, including Gdańsk, Gdynia and Sopot – the patterns which the local authorities have been

trying to changes in order to meet the paradigm of sustainable mobility.

At the present stage of the COVID-19 pandemic development in Poland it is really difficult to indicate further research directions. The issues mentioned in this study suggest the necessity to carry out a detailed analysis of: long- and short-term consequences of implementing the mobility restrictions as well as real changes in mobility patterns affecting the structure of transport performance. However, it seems that the above-mentioned issues, at least partially, result from changes in perception of usefulness or attractiveness of a particular means of transport which may be a direct result of experiencing what life during a pandemic looks like.

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