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ABSTRACT

The purpose of the paper is to show how the national border closures within the EU-27 have an impact on changes in potential accessibility in individual transport at the NUTS3 level. We are referring to the situation that occurred during the COVID-19 pandemic outbreak in Europe in March 2020. The study distinguishes between long and short trips, comparing the situation before the pandemic with that after the complete closure of national borders by all EU countries, thus showing which areas of the EU will suffer from accessibility losses for both long and short trips. We conclude that the spatial pattern of regions at risk of peripheralisation for short trips well defines the zones in which a serious crisis threatens local cross-border commuting. The threat of peripheralisation for long trips mainly concerns those parts of countries which are closer to the demographic and economic core of the European Union. Nevertheless, it is also compounded by other factors: including the national settlement and road networks.

1. Introduction

One of the basic cornerstones of Union citizenship established by the Treaty of Maastricht in 1992 is freedom of movement and residence for persons in the European Union. The gradual abolition of internal borders under the Schengen agreements was followed by the adoption of Directive 2004/38/EC on the right of EU citizens and their family members to move and reside freely within the EU (EC, 2004). Up until March 2020 the European Union has had full border permeability with the exception of Bulgaria, Romania, Croatia and Cyprus, as well as Ireland, which negotiated opt-outs from Schengen and continues to operate border controls with other EU member states. The signatories of the Schengen Agreement, which also include Norway, Switzerland, Iceland and Liechtenstein, have retained the right to introduce border controls in particularly justified cases. As a rule, however, such restrictions were exceptional and short-lived. Some deviations from this rule on selected border points or sections include actions in response to the influx of refugees in 2015. However, it has only been the COVID-19 pandemic that has caused far-reaching consequences in the free flow of people across intra-EU borders. At the end of March 2020 the outbreak of the pandemic had resulted in hundreds of thousands of infections and thousands of deaths on the European continent, and also had a strong impact on the continuity of many European Union policies, including the basic principles of the common transport policy. In March 2020, most EU countries introduced some kind of control over their external borders, and some countries decided even to close their borders completely to passenger traffic. In turn, on March 17, 2020, EU leaders decided to close the EU’s external and Schengen borders. These unprecedented events in the history of the European Union are the subject of analyses in this paper from the point of view of their potential impact on changes in the accessibility/peripherality of the EU-27 regions.

The novelty of the paper lies in the fact that the reversal of the trend of increasing border permeability, the degree of openness of borders, has not yet been studied or even simulated. Existing analyses of changes in border traffic, which is a basic measure of permeability, concerned the impact of specific events, e.g. the impact of the attacks of September 11, 2001 on traffic between the United States and Canada (Olmedo and Soden, 2005; Hennher, 2005; Maoh et al., 2016), or the effect of the Russian invasion of Ukraine in 2014 on movement between Poland and Ukraine (Komornicki and Wiśniewski, 2017). These studies focused on the border traffic itself and did not take into account the population distribution and cross-border transport infrastructure on both sides of the border in the context of a possible increase in the region’s peripherality. The possibility of such an approach was proposed by studies on...
accessibility issues undertaken in a cross-border perspective (Spiekermann et al., 2015; Rosik et al., 2015). However, in this case as well, no simulations were carried out that assumed a sharp reduction in the permeability of political borders. The focus was rather on the scale of effects that investments in one country can have in neighbouring countries (Więckowski et al., 2014; Komornicki and Spiekermann, 2018). Comparisons of accessibility simulations at the intranational and international level were implemented (Spiekermann et al., 2015), but their purpose was to formulate the tasks for transport policy at various spatial levels (Rosik et al., 2015), to show the diversity of Europe in terms of GDP per capita and potential quotient (Rosik et al., 2020), or to compare cross-border accessibility to accessibility within the national territory (Jacobs-Crisioni and Koomen, 2017; Christodoulou and Christidis, 2019) rather than assessing the effects of a possible lockdown of borders.

The purpose of the paper is to answer the question of how extreme black swan events like the COVID-19 pandemic may influence changes in potential accessibility in individual transport at the NUTS3 level and what is the spectrum of policy responses. The study distinguishes between long trips and short trips, comparing the situation in conditions of full border permeability (in general the situation before the coronavirus pandemic) and the probable variant of the complete closure of national borders by all EU countries, showing which areas of the EU are most likely to suffer from accessibility losses as a result of closing intra-EU borders for both long and short trips.

The article is divided into six sections. In section two, we briefly review the literature in the context of border permeability and the vulnerability of sections of the border. In the third section, we present a typology of the main restrictions on the national borders within the European Union that were introduced in March 2020. In the fourth section, we present the assumptions of the potential accessibility model at European level. In the fifth part, we present the outcomes of the decrease in the level of potential accessibility at NUTS 3 level as a result of the closure of national borders within the EU. In the sixth section we present conclusions and in the seventh section we offer a discussion of the implications of the findings.

2. Trends in border permeability and rare risks

2.1. Trends in increasing permeability

Borders have been the subject of scientific research (political geography, political science, regional studies) for many years as well as a reference point for spatial analysis. After the fall of the Iron Curtain in 1989, the boundaries were mainly analysed from the point of view of reducing their function, resulting in a growth in permeability. As Guild (2001) indicates the increasing mobility of people, globalisation, transnationalisation and the political integration of Europe have fundamentally changed the meaning of borders. For this reason, the situation of individual cities and regions has been increasingly seen as a derivative of cross-border external impacts (Castells, 1998; Taylor et al., 2010). International flows have gained a key place in modern economics (Krugman, 2014) and socio-economic geography, and regional development has become increasingly dependent on cross-border interactions (Dühr et al., 2010). Changes in Central Europe, including the signing of the Schengen Agreement by the majority of EU states, as well as the implementation of numerous cross-border projects (supported by the EU) meant that the process of increasing the permeability of European borders was considered irreversible (Martinez, 1994). A further gradual reduction of border restrictions was anticipated as the spatial integration processes progressed (Corvers and Giaoutzi, 1998). Although parallel strengthening of the border restrictions of the EU’s external borders was observed (Jakubowski et al., 2017), it was expected that over time they would also become more permeable. Thus it was assumed that “open borders” are an “innovation” that will spread to other countries of the region and the world. Doubts about the linear nature of changes in the permeability of European borders appeared after 2015 as a result of the migration crisis which led to the return of border controls on certain sections (Rheindorf and Wodak, 2018; Vollmer, 2016), the Russian invasion of Ukraine (e.g. suspension of minor border traffic agreements, e.g. between Poland and Russia) (Komornicki and Wisniewski, 2017) and Brexit (Lim, 2018; Portes and Forte, 2017).

2.2. Road network vulnerability to rare risks

Generally, the listed events were selective in terms of space (specific sections of borders) and time (short periods). The sudden and sharp limitation of the permeability of borders across the European Union in March 2020 was a completely unprecedented and unpredictable phenomenon, a so-called black swan (Taleb, 2007). In this context, border sections and the closure of borders should be understood in the context of the road network’s vulnerability to rare, big risks (Berdica, 2002) or sudden, unpredicted events (Jenelius et al., 2006). So far, the vulnerability of the road network has mainly been analysed in the context of natural disasters, such as earthquakes (Chang and Nojima, 2001), hurricanes (Sohn, 2006), fires (Gulliani et al., 2012), floods (Pregnolato et al., 2017; Moghadas et al., 2019; Singh et al., 2018) and also terrorist bombings (Faturechi and Miller-Hooks, 2014). As indicated by Jenelius et al. (2006), in very rare cases, when it is difficult to estimate the probability of an event, the term conditional vulnerability or exposure is used in the context of the criticality of a certain component (link, node, groups of links or nodes, here – border crossing points) (overview of empirical research on transportation resilience in Wan et al., 2018). In this context, one of the effects of unexpected events, i.e. the closure of borders, is a sudden drop in accessibility and, consequently, an increase in the peripherality of regions, in particular border regions. To assess the scale of the phenomenon, a comparison is made of the situation before and after the event. As Sohn (2006) indicates in the context of earthquakes, loss of accessibility should be defined as the ratio between the accessibility levels in post-earthquake and pre-earthquake conditions. Following this lead, we analyse changes in accessibility/peripherality before and after the occurrence of a black swan, a real earthquake for European transport policy, i.e. the COVID-19 pandemic.

3. The response to the COVID-19 pandemic. Intra-EU27 borders

3.1. Permeability of borders in the European Union before the COVID-19 pandemic

In 2011, work began on the modification of the Schengen Agreement, which resulted in the creation of the possibility of the temporary reintroduction of internal border controls for foreseeable events, such as an important sporting event or a major political meeting. Nevertheless, a decision „would be taken at the European level on the basis of a proposal by the European Commission backed by a ‘qualified majority’ of Member States’ experts. The grounds on which such a decision could be taken will remain the same as today: that the measure is necessary in order to off-set a serious threat to public policy and internal security. As a general rule, controls could then be allowed at designated borders for a renewable period of 30 days” (EC, 2011).

Accordingly, up to 2015 temporary border controls were sporadically introduced for short periods of time mainly for political summits and conferences, i.e. G7/G8, G20, NATO; great sporting events, i.e. Euro 2008, Euro 2012, and the visits of important and influential people in a given country. This situation of exceptional, short-term and occasional checks was first changed by the outbreak of the 2015 migration crisis in Europe. Due to the uncontrolled influx of refugees and the growing terrorist threat, some Schengen countries have restored internal border controls, and the restrictions have been extended several times. Before 2020, however, there was no situation that would change the Schengen Agreement in principle at all EU-27 internal borders.
3.2. The general response to the COVID-19 pandemic

The coronavirus disease, originating in Wuhan in China in late 2019, came to Europe on 24 January when the first case was confirmed in Bordeaux, France. Just over a month later, i.e. on February 28, the number of cases in Europe exceeded 1,000, and already two weeks later, i.e. on March 13, the number of fatalities due to COVID-19 in Europe exceeded 1000. On March 17, all countries on the European continent had already reported cases of the illness. The epidemic entered the next phase, and in the second half of March the European Union became the world epicentre of COVID-19, resulting in subsequent actions by states aimed at limiting the permeability of borders. The peak of these activities took place between March 12 (Hungary) and March 20 (Belgium).

During this period, the majority of European countries began to decide on various forms of control, restriction, and finally even a ban on traffic across their borders. In this paper, we focus on restrictions on the movement of people using road transport. In principle, all European Union countries have introduced restrictions in this area. However, these activities were not coordinated in any way. The significant limitations on the permeability of borders resulted from: a) the reintroduction of border controls at internal borders in the Schengen area; b) the introduction of sanitary controls, which significantly extend the time of border checks, in extreme cases as on the Polish-German border even in excess of 24 h; c) limitations on the number of places where the border may be crossed, i.e. re-introducing “border crossings”.

In general, the transport of goods was allowed everywhere within the EU-27, and thus drivers were excluded from further restrictions. Moreover, all countries allowed their citizens or persons with permanent residence status to return home, predominantly with a 14-day home quarantine order. The EU-27 states generally did not formally limit their citizens’ right to travel abroad (with a few exceptions of countries in full lockdown, like Spain or Italy, or countries with nationwide quarantine like Lithuania). However, even in the case of the obligation of a two-week home quarantine after returning from a possible departure, in those countries where there were no separate provisions for daily commuting across the border this condition de facto meant a ban on these trips (as in Poland, March 27).

3.3. A typology of new national border regimes in Spring 2020

The greatest variation in the approach to entry was for foreigners. In this case, the starting rule in many countries was a general ban with some exceptions in certain situations. In practice, however, foreigners were classified into groups and in many cases such entry was in the end even allowed. Three types of such division can be distinguished, which are also models of the border regime during the pandemic:

- According to border section. Foreigners are admitted without control only from some neighbouring countries, predominantly those where the scale of the epidemic is smaller or where many employees needed by the economy come from. An example is Germany admitting entry without control through sections of the border with Poland and Czechia, while at the same time restoring border control on the border with Switzerland, France, Austria and other Western European countries;
- According to citizenship. Restrictions on entry from countries where the number of cases is the highest due to the threat of an epidemic (e. g. restrictions introduced in Bulgaria);
- According to travel destination (origin-destination traffic and transit traffic). This applies to residents of the border area working in a neighbouring country or people in transit who are excluded from the ban and allowed to travel, at least for a given period of time. In the first case, this applies to, for example, commuters to Luxembourg. In the second case - most countries agreed on the creation of special temporary humanitarian corridors, e.g. a 72-h corridor for Latvians and Estonians travelling through Poland and Lithuania from Western Europe.

It should be added that during March 2020, many countries changed the scope of existing restrictions. Usually these changes consisted of tightening procedures. This was manifested in restrictions on further groups of travellers, e.g. also on cross-border commuters on a daily or weekly basis as at the Polish borders.

From the point of view of the perception of accessibility, it can be assumed that the restriction of the entry of foreigners and the obligation of quarantine when one’s own citizens are returning is de facto closing the border to passenger traffic. Returns to the country of citizenship are one-off trips. Therefore, they cannot be equated with constant spatial interaction between regions on both sides of the border.

On the other hand, the scope of the restrictions introduced may be of significant importance in the interpretation of the accessibility pattern for trips thus obtained both long and short. This particularly applies to two considerations: a) maintaining the possibility of shuttle traffic for cross-border employees (without quarantine; short trips); b) the possibility of transiting through third countries (long trips).

The restrictions introduced can also be compared to the degree of epidemic development on both sides of the border (see Fig. 1). From this point of view, some restrictions are a clear response to the existing threat (e.g. Slovenian-Italian border or Portuguese-Spanish border), while others are preemptive in advance (e.g. Finnish-Estonian border and many border sections in Central and Eastern Europe). The level of threat also explains the asymmetry of the solutions adopted on some sections of borders, e.g. restrictions for German citizens entering Czechia and Poland, with free entry of Poles and Czechs to Germany. Another important reference point may be the scale of cross-border employment. In this case, restrictions can have a particularly strong economic and social effect. This is clearly a concern for those countries where foreign workers are an important element of the labour market in the border area (Germany, Austria, Belgium) or in the whole country (Luxembourg).

4. Methods

4.1. Peripheralisation and the potential accessibility index

Peripheralisation discourse and the degree of peripheralisation itself are the subject of many papers and some authors agree that “peripheralisation becomes a fuzzy concept” (Eder, 2018; Crone, 2012; Kühn, 2013). In our paper we follow the approach by Schürmann and Talata (2000) where “a peripheral region is defined as a region with low accessibility” (p. 6). The risk of peripheralisation is therefore understood in our paper as the risk of lowering the level of potential accessibility.

There is a great variety of methods used to calculate accessibility (reviewed by, among others, Geurs and Ritsema van Eck, 2001). The research method used in this paper is the potential accessibility index, which is characterised by the fact that with increasing distance or travel time, the attractiveness of the destination, e.g. population or GDP, decreases (Spiekermann et al., 2015). At the European Union level,
accessibility/peripherality studies, mainly applied potential accessibility indicators, have been conducted since the early 1980s (review in Copus, 2001 and Spiekermann et al., 2015). There is a relationship between the time of study and the territorial scope of the European Union (or before 1993 - the European Economic Community), starting from nine and twelve countries in the 1980s (Keeble et al., 1982, 1988) to twenty-seven (Schürmann and Talaat, 2000; Spiekermann et al., 2015). These studies are targeted at the concepts of regional cohesion and the core-periphery pattern (Copus, 2001; Spiekermann and Schürmann, 2007). Nevertheless, they lacked a reference to the impact of impedance on accessibility results. The valuable exception is the ESPON TRACC report (Spiekermann et al., 2015), where the distance decay parameters are used to illustrate the core-periphery pattern in the European Union (Schürmann and Talaat, 2000; Spiekermann et al., 2015). These studies are targeted at the concepts of regional cohesion and the core-periphery pattern (Copus, 2001; Spiekermann and Schürmann, 2007). Nevertheless, they lacked a reference to the impact of impedance on accessibility results. The valuable exception is the ESPON TRACC report (Spiekermann et al., 2015), where the distance decay parameters are used to illustrate the core-periphery pattern in the European Union (see also Biosca et al., 2013). The aforementioned report and the paper provided by the authors in Rosik et al. (2020) are also unique in the way that they present the results of the accessibility calculations both at the intra-European and intranational perspective.

4.2. Formula for potential accessibility in the international dimension

Generally, if $A_i$ is defined as the level of accessibility of transport zone $i$, and the car travel time between a pair of transport regions $i$ and $j$, $t_{ij}$ is a chosen element in a distance decay function $f(t_{ij})$, and the measure of attractiveness of the travel destination is the population in transport zone $j$, $POP_j$, the general formula for the population potential, $A_i$, is as follows:

$$A_i = \sum_j POP_j f(t_{ij})$$

One of the most frequently used distance decay functions is the exponential one (Beria et al., 2017; Stepniak and Rosik, 2016, 2018):

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

where the $\beta$ parameter differentiates the degree at which the attractiveness of the destination decreases. The value of the parameter depends on the spatial scope of the study. At the European level it usually

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Fig. 1. Number of confirmed cases COVID-19 at the regional level; March 23, 2020.
takes values in the range 0.003–0.01, while at the intranational level these values are respectively higher (Rosik et al., 2015). Following a half-time (Spiekermann et al., 2015) or half-life approach (Osth et al., 2014), which is based on the assumption that destination attractiveness decreases by half at the observed median travel time (Rokicki and Stepniak, 2018), we call it CATCH-time, which is a time value that Cuts destination Attractiveness To Circa Half of its original size (Rosik et al., 2020). We choose respectively beta parameters of 0.005775 and 0.023105 to distinguish long and short trips (Rosik et al., 2015). The first value assumes 120 min trips as median. The first value assumes 120 min trips as median. It is adapted to calculate the indicator values for long-distance trips such as tourism or visiting friends and relatives connected with holiday journeys and migration flows. The second value corresponds to a CATCH-time value of 30 min and is used to estimate the accessibility potential for short-distance trips, e.g. cross-border commuting. The total value of the potential indicator applied for in terms of relative and absolute changes in the overall value of the accessibility indicator between the two extreme variants. The first option of full permeability of borders within the EU-27 contains all three potentials, including external (international) potential. The second option is limited only to the sum of selfpotential and intranational potential, without the possibility of travelling between countries as a consequence of closure of all national borders within the EU. This approach shows the framework in which transport policy can be formulated.

5. Results

5.1. Accessibility pattern. Full border permeability

The distribution of potential accessibility obtained in Europe in a situation of full border permeability confirms the results of the accessibility pattern obtained by other authors (Spiekermann et al., 2015). Highly urbanised and densely populated areas are characterised by a high level of accessibility for short trips. In turn, for long trips, the highest level of accessibility is in the area of the so-called Blue Banana (Brunet, 1989; Faludi, 2015). Accessibility levels decrease gradually for those regions located farther from the European core, with the decline being the fastest towards the least populated Scandinavia (Fig. 2).

In addition to the diversity related to the distribution of population and the settlement network, the accessibility pattern, assuming full permeability of national borders, is also influenced by the road network and the proximity of the external borders of the EU-27. The transport component (Geurs and Ritsema van Eck, 2001) remains dependent on the transport policies and the policy that is implemented in relation to the border regime (waiting times at the EU’s external borders). The impact of the transport policy is mainly expressed in investment activities, resulting in the improvement of the quality of infrastructure and, consequently, the shortening of travel time. Especially in the case of long trips, the consequences of the development of the TEN-T road network are visible on the periphery of the European Union along transport corridors. There is an imbalance in the concentric decline in accessibility as it moves away from the European core. This effect can be observed along the new motorways built from the German border in Poland and

![Fig. 2. Road accessibility EU-27 pattern for short and long trips.](image-url)
the Czech Republic to the centres of these EU states, as well as from the Hungarian border in Romania. Summing up, after the EU enlargements, the development of the road network, supported by the cohesion policy, improved the accessibility of some regions of Central Europe. Nevertheless, the positive effect was spatially selective (Rosik et al., 2015).

In the case of short trips, the new infrastructure, financed mainly from EU funds, sometimes contributed to the emergence of internal peripheries in some countries (Komornicki 2019). This is especially visible in larger countries with a polycentric settlement structure that have a peripheral location relative to the EU core, e.g. Spain, which is polycentric in terms of size index (see ESPON, 2005) as well as Poland and Romania. The consequences of the closure of the borders as a result of the COVID-19 pandemic overlapped this historically shaped spatial structure. The effects of the EU’s transport policy, especially in peripheral areas, were subjected to an unexpected test of the suitability of individual road sections in the conditions of closure of national borders.

5.2. The main factors behind the effect of the closure of national borders on loss of accessibility

Depending on trip length and the way we track loss of accessibility (absolute vs percentage changes), different EU-27 regions are affected in different ways by the closure of national borders. Nevertheless, there are two factors that have the biggest impact on the extent of change in accessibility as a result of closing national borders. These are as follows: (1) The population of the country compared to the population in neighbouring countries; (2) Road travel time to the nearest region.

Fig. 3. Percentage and absolute potential accessibility losses in the EU-27 NUTS3 regions after the closure of national borders. Short and long trips.
located within the European core (Blue Banana).

5.2.1. The population of the country compared to the population in neighbouring countries

In general, less populous, small and medium-sized countries surrounded by densely populated border areas of the most populous EU states are the most dependent on international accessibility. These include, in addition to Benelux, Slovenia (especially in percentage terms), and to a lesser extent also Denmark, Austria, Czechia, Slovakia, Hungary and the Baltic States (see Figs. 3 and 4). Generally, for the entire EU-27 area the absolute loss of accessibility is more significant in the European core regions, while the percentage changes show a more even distribution of accessibility losses as a result of closing borders across the entire research area.

The area that is the least resilient to border lockdown is the border between the Benelux countries and Germany. The results of the study indicate that it is no accident that the Treaty on the European Union was signed in Maastricht and many EU offices are located in Luxembourg. Luxembourg and Maastricht (together with Eupen and Venlo) occur at least three times in the ranking of the ten most affected regions in the context of percentage and absolute accessibility losses for long and short trips (see Table 1).

The results obtained (Fig. 4) indicate that countries whose own population is higher than the total population of neighbouring countries are generally characterised by low rates of decline in accessibility after border closure. In the case of countries where this relationship is the reverse, the situation is more variable and it can be presumed that it depends on other factors. The spatial concentration of the population in the neighbouring country turns out to be important. Therefore, the loss of accessibility in the Netherlands, Belgium, Austria or the Czech Republic is significant due to the proximity of densely populated areas in Germany, while in Lithuania and Portugal the accessibility loss is much smaller because these countries are adjacent to sparsely populated areas of Poland and Spain respectively. The relatively small decrease in accessibility in the peripheral states may also result from a poorer quality of infrastructure. This is the case, for example, in the aforementioned Lithuania (the Via Baltica route has not been completed in Poland), but also in Bulgaria (infrastructure deficiencies in both Bulgaria and Romania). Foreign destinations, including the European core, then remain distant (in terms of travel time), and thus less significant in the accessibility model, especially with rapidly declining distance decay for short trips. This confirms the previous conclusions for transport policy at EU level (Komornicki and Spiekermann 2018) that decisions on road investments must take into account the spillover effects in neighbouring countries.

Thus, the ex-ante evaluation of investment activities from the point of view of changes in accessibility should be of a cross-border nature and carried out in variants that take into account the assessment of the situation were all or some sections of national borders to be closed.

5.2.2. Road travel time to the nearest region located within the European core (Blue Banana)

The road travel time to the European core is strongly correlated with the absolute loss of accessibility for long trips, regardless of the EU state analysed. In general, the southern and northern fringes of the EU (vertical rectangles on chart 5) suffer less after closure of national borders than the central European states (horizontal rectangles on chart 5). For both long and short trips, the border sections most sensitive to the loss of international accessibility are those along borders with countries located closer to the European core. This is particularly visible in large EU states with an external EU border, such as in Poland and Romania, where different parts of the country clearly contrast with one another - the west strongly depending on international accessibility while in the east, these changes are not so visible.

Fig. 4. The population-population in neighbouring countries ratio vs the loss of accessibility after the closure of national borders.
The reasons for the relationships obtained are: (a) the concentration of the population in the Blue Banana, (b) the concentricity of the potential model; (c) the spoke arrangement of the European road infrastructure towards the European core. Peripheral countries also often have poorly developed transport connections between them (e.g. lack of the so-called Via Carpatia; cf. Rosik et al., 2018), which reduces the importance of large destinations in neighbouring countries. This is an argument for a more even development of transport infrastructure and a recommendation for the construction and/or modernisation of routes between the peripheral countries of the EU so that in crisis conditions, such as a pandemic, it is possible to use the potential of various neighbouring countries.

5.2.3. Other factors

Apart from the two factors mentioned above which have the greatest impact on the decrease in accessibility, there are number of other factors which have a limited impact in particular countries or areas and whose quantification is more difficult. There is for instance the road travel time to the nearest national intra-EU border which turned out to be important in countries in Central Europe such as Germany, Czechia or Austria.

Another important variable is the difference in population density in border areas on both sides of the border. For short trips, border regions neighbouring densely populated areas in other countries, such as the Moravian-Silesian region in Czechia (location next to Upper Silesia, Poland) and Pyrénées-Atlantiques in France (neighbouring the densely populated Basque Country, Spain), are the most vulnerable to the loss of international accessibility. Interesting examples are the regions of Reutte in Austria (near the German border) and Terneuzen in the Netherlands (near the Belgian border), losing respectively, after closure of national borders, more than 80% and 70% of their level of accessibility. These regions are “separated” from the rest of their own countries by a mountain range (Reutte) or the Scheldt estuary (Terneuzen).

It is worth adding that short trips are mainly carried out by cross-border commuters. The scale of cross-border commuting in the EU is particularly large in areas adjacent to the German border, Benelux countries, areas near the southern and eastern borders of Austria (with Slovenia and Hungary), and also the Danish-Swedish border, in particular the Copenhagen - Malmö agglomeration, Polish-Czech, Czech-Slovak, Hungarian-Romanian, and locally the French-Spanish border. It is a paradox, that exactly those factors that make certain regions successful (e.g., ability to engage in more cross border spatial interaction), could now hurt in the case of severe border restrictions.

In addition to the most important factors influencing the decline in accessibility due to the closure of national borders listed in this paper, other factors potentially affecting the extent of change in accessibility include:

(a) The structure of the national urban system (polycentricity vs monocentricity; centralism vs dispersion, etc.). However, our preliminary research carried out during the work on this paper did not bring the expected results. We took into account the relationship between the level of polycentricity in the EU countries based on the ESPON 1.1.1 (ESPON, 2005) project (size and location indices) and the loss of accessibility as a result of border closure;
(b) The tortuosity of the border. The complicated course of borders results in greater loss of accessibility (peripheralisation) of the area after closure of the borders. One of the ways of calculating the accessibility indices on both the intra- and international level, in particular for border regions, is to use the network efficiency index (see Christodoulou and Christidis, 2019). The number of crossing points is also important (Furmankiewicz et al., 2020);
(c) The quantitative and qualitative condition of the transportation network, in particular in border areas which may be more transit-
Percentage and absolute potential accessibility losses in the ten most affected EU-27 NUTS3 regions. Short and long trips.

| Region | NUTS3 | Percentage loss | Absolute loss |
|--------|-------|----------------|---------------|
| Austria | Reutte | 80.5 | 72.48 |
| Netherlands | Venlo | 212.6 | 190.37 |
| Luxembourg | Luxembourg | 99.1 | 98.07 |
| Luxembourg | Luxembourg | 73.48 | 72.70 |
| Netherlands | Venlo | 71.0 | 68.26 |
| Netherlands | Maastricht | 168.6 | 157.80 |
| Slovenia | Murska Sobota | 96.5 | 92.39 |
| Belgium | Eupen | 71.3 | 68.27 |
| Netherlands | Terneuzen | 70.5 | 68.82 |
| Belgium | Eupen | 67.5 | 65.93 |
| Germany | Kleve | 93.4 | 90.12 |
| Slovenia | Ajdovscina | 96.4 | 92.77 |
| Belgium | Verviers | 69.9 | 66.49 |
| Netherlands | Maastricht | 69.7 | 66.30 |
| Netherlands | Weert | 120.2 | 117.27 |
| Slovenia | Koper | 96.4 | 92.39 |
| Belgium | Venlo | 69.8 | 66.29 |
| Belgium | Arlon | 68.3 | 64.98 |
| Belgium | Arlon | 68.3 | 64.98 |
| Belgium | Hasselt | 68.1 | 65.67 |
| Belgium | Hasselt | 68.1 | 65.67 |
| Belgium | Hasselt | 67.8 | 65.40 |
| Slovenia | Kranj | 96.1 | 92.20 |
| Belgium | Verviers | 67.4 | 64.98 |
| Belgium | Limburg | 92.5 | 88.80 |
| Luxembourg | Luxembourg | 63.0 | 60.50 |

6. Conclusions

A sharp reduction in accessibility level, reaching even over 95% for long trips, can be treated as an additional factor, in addition to the economic crisis, intensifying the economic problems of the regions in early spring 2020. This phenomenon has a strong territorial dimension and is a premise for place-based policy. It is crucial to assess the impact of limiting the permeability of borders due to the COVID-19 pandemic on socio-economic, as well as territorial cohesion, processes.

The spatial pattern of regions at risk of loss of accessibility (peripheralisation) determined for short trips well defines the zones in which a serious crisis threatens local cross-border commuting. Closing borders and halving already developed or emerging cross-border labour markets can be particularly acute for local people. It confirms that despite several decades of support for cross-border cooperation, it has still not been possible to create cross-border functional areas that could be the subjects of mobility policy in crisis conditions. The research shows that functional systems that do not fit within political boundaries have developed in many places in the European Union. The crisis situation related to the pandemic resulted in a sudden reactivation of the functions of borders as spatial barriers, and as a consequence - a loss of mobility. In this context, the results obtained demonstrate the need for a more active policy in relation to cross-border functional areas (e.g. under the European Territorial Cooperation). This recommendation concerns in particular the creation of an appropriate institutional framework for cross-border crisis management.

It seems important to note that the threat of peripheralisation mainly concerns those parts of countries which are closer to the demographic and economic core of the European Union. This applies especially to the results of the analysis conducted for long trips. This effect is mainly a consequence of the distribution pattern of the population on the European continent. In some countries, however, it is also compounded by other factors: the national settlement and road network, in particular the TEN-T corridors. While the settlement network is the result of hundreds of years and historical processes, the transport system has been developed in recent decades. In particular in Central and Eastern Europe, investments were primarily focused on routes connecting the so-called new member states with the EU core (Komornicki, 2019), including primarily Germany. This resulted in a rapid improvement in accessibility at EU level, but not always also at the intranational level (Rosiś et al., 2015). Motorways leading exclusively to borders away from some medium-sized border cities have become “of little use” in increasing the accessibility of such centres after the closure of the borders. This statement is important from the point of view of transport policy, because it can be a premise for investment priorities and the phasing of road investments in the future in such EU states as Bulgaria or Romania, or in general for the initial project stages of international high speed train connections.

7. Discussion

At the beginning of August 2020 it is difficult to judge how long the situation of the restrictions at borders will last and whether, or when, the border closure situation will repeat itself. Nevertheless, what happened in March 2020 it is a kind of experiment based on the results of which one can model the vulnerability of regions or their resilience to the closure of internal borders from the point of view of a decrease in the level of accessibility or a sudden increase in international peripherality. Further research should be continued in this area resulting not only in...
the expanding of knowledge about accessibility losses, but this should also lead to checking for a COVID-19 border effect, mainly in the context of international trade, daily cross-border commuting and migration flows within the European Union.

The study that is being conducted can be treated more broadly as an attempt to assess changes in accessibility in crisis situations when the free movement of people is restricted. This makes it possible to look at the transport infrastructure from the point of view of its usefulness at various geographical scales. This may be related to the perspectives of limiting the transport intensity and changes towards regional circular economies that are under consideration. Such a scenario was considered e.g. in the study of the development prospects of the Baltic Sea Region until 2050 (ESPON, 2019). In this context, the COVID-19 pandemic is a simulation of a situation in which there is a forced shortening of travel length. The results obtained lead to the conclusion that the effect of such actions would show spatial variation, especially if the catchment areas are limited by national borders (and not functional systems).

In future studies, the spatial picture of the decline in accessibility should be superimposed on the changes in overall mobility that occurred during the pandemic and those that could be triggered by it. It should be emphasised: (a) a general reduction of international mobility in Europe which is observed in the middle of 2020 even after the opening of borders and in the tourist season (Google LLC), (b) modal changes, including a return to individual car transport, (c) the declared idea of shortening production chains. These changes will have a major impact on the future transport policy of the European Union and the Member States.

Taking into account the results of the research described above may indicate changes in the current shape of policies:

- increasing support for infrastructure in cross-border functional areas, with simultaneous institutional integration of these areas;
- a scenario-based approach to the evaluation of investment projects, including the evaluation of the impact of individual projects on territories in crisis conditions, e.g. full or partial closure of borders;
- cross-border evaluation of investment projects in terms of spatial spillovers, i.e. the territorial impact of investment affecting accessibility in the neighbouring country;
- greater focus on regional and local road infrastructure, ensuring maximum use of links to regional growth centres;
- undertaking cross-border investments between the EU’s peripheral states in parallel to the Blue Banana.

Author statement

Piotr Rosik: Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing. Tomasz Komornicki: Writing – Original Draft, Writing – Review & Editing. Patryk Duma: Data curation, Visualization, Investigation. Slawomir Goliszek: Data curation, Visualization, Investigation.

Declaration of competing interest

Authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

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