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TRANSPORT NETWORK INFRASTRUCTURE IN THE CONTEXT OF POPULATION CHANGES IN FIVE EU STATES (1960–2020)

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Abstract. Changes in accessibility that took place in Western Europe, and then also in Central and Eastern Europe, in recent decades were associated, on the one hand, with the processes of intensively expanding transport infrastructure networks, and, on the other hand, with demographic changes. Transport policy in some countries was based on a strategy of sustainable growth, where the development of infrastructure, both at the national and regional level, progressed in parallel with changes in the settlement structure. However, in other countries or regions it acted reactively, following the processes of population growth and concentration, or proactively, i.e. anticipating these changes. Both reactive and proactive policies are unsustainable, either in the national or in the regional sense. However, it is crucial to look at the aspect of unsustainable increase in accessibility in terms of the sequence of events, stages and policy prioritization decade by decade. The model of potential accessibility used for several countries at the same time allows to notice certain regularities related to the mutual impact of transport and spatial policy. The aim of the paper is to indicate effects of spatial and transport policies in the context of population changes, infrastructural changes and, in general, changes in potential accessibility, decade by decade (1961–2021) from the point of view of spatial policy objectives for five European countries.

Keywords: accessibility changes, transport infrastructure, demographic changes, spatial and transport policy, potential accessibility model, sustainable and unsustainable growth.

Introduction

The changes in accessibility that have occurred in Central and Eastern Europe (CEE) over the last few decades have been related, on the one hand, to the processes of intensive expansion of the transport infrastructure network, in particular after accession to the European Union (EU) in 2004, and, on the other hand, to demographic changes. Demographic changes occurred during the transition from a centrally planned economy to a market economy, particularly at the turn of the 1980s and 1990s. During this period, overall population growth collapsed, and in some countries of the region, population decline accelerated. In subsequent years, the areas experiencing a decrease in population expanded due to both declining fertility rates and migration.

In recent decades, we have observed an intense process of suburbanization, which in some CEE countries resulted in the depopulation of city centers and a simultaneous population increase in agglomerations, suburbs, and so-called ‘bagel communes.’ This process coincided with the depopulation of both national and regional peripheries (the so-called internal peripheries). Theoretically, this led to a reduction in regional inequalities in accessibility because the populations of the most accessible city centers and the least accessible peripheries both decreased.

A thorough empirical analysis of changes in regional accessibility at the level of the entire country requires the use of a potential accessibility model over a long period of time. In this study, the potential accessibility model was used for several countries, including two largest countries from CEE, i.e. Poland and Romania, and, for comparison, also countries from Europe Western Europe (in this case, three countries selected were large enough both in terms of population and area, i.e. Germany, France and Spain). Analyzing accessibility for as many as five countries at the same time allows us to notice certain regularities related to the interaction of transport and spatial policies in different countries.

The aim of the paper is to indicate changes in the effects of transport policy in the context of demographic and infrastructural changes and, in general, changes in potential accessibility decade by decade (1960–2020) from the point of view of spatial policy goals over six decades. The transport policy of some countries was based on a strategy of sustainable development, where the development of infrastructure, both at the national and regional level, progressed in parallel with changes in the settlement structure. However, in other countries or regions it acted reactively, following the processes of population growth and concentration, or proactively, i.e. anticipating these changes. Both reactive and proactive policies are unsustainable, either nationally or regionally. However, it is important to look at the aspect of uneven accessibility growth in the context of a sequence of events, stages and policy prioritization decade by decade.

The structure of the paper is as follows. After the introduction, key literature items are presented regarding the analysis of changes in accessibility as a result of investments and infrastructure expansion programs in the five studied countries. The next sections briefly describe the potential accessibility model used and the study area. Next, the results of the analysis are presented to end the article with conclusions and a short discussion regarding further possible methodological developments of the analyzed topic.

Literature review. Comparative analyzes of accessibility between countries

Comparative analyzes of the overall level and regional differentiation of accessibility between countries are very rare. Accessibility is much more often studied in terms of European or cross-border accessibility (review of this type of analysis in Spiekermann et al., 2015a) usually with the assumption of a specific permeability of borders. An exception is the compilation of accessibility analyzes in the form of a case study as part of the ESPON TRACC project (Biosca et al., 2013; Spiekermann et al., 2015b), where accessibility study with the same methodological background was prepared for some countries and regions of the ESPON space, i.e. in The West Mediterranean region (Spain and France) , Northern Italy, Bavaria, Czechia, Poland, the Baltic States and Finland. This statistical comparative analysis was carried out at the LAU 2 level for six accessibility indicators, i.e. (1) Access to regional centres; (2) Daily accessibility of jobs; (3) Regional potential accessibility; (4) Access to health care facilities; (5) Availability of higher secondary schools and (6) Potential accessibility to basic health care. Also in the statistical approach for 2015, a comparative analysis of the level of intra-national accessibility for all countries in Europe was carried out in the context of the potential quotient to GDP by Rosik et al. (2020) and in the context of closing national borders by Rosik et al. (2022b). For the period 2006–2016, a comparative analysis was also made of changes in potential accessibility in Baltic Europe (Komornicki & Spiekermann, 2018). The potential accessibility method was also used to assess the effects of individual transport investments planned on a transnational level, such as the Via Carpathia road corridor (Rosik et al., 2018).

Our paper aligns with a well-established tradition of analyzing accessibility changes using a dynamic approach at the national level. A concise review of such analyses can be found in Stępniak and Rosik (2018). Some studies examining the impact of transport and land use components analyze and compare their respective effects on accessibility changes, such as Rosik et al. (2025b) for France, Spain and Poland, Condeço-Melhorado et al. (2017) and Lopez et al. (2008) for Spain, or Geurs and Ritsema van Eck (2003) for job accessibility in the Netherlands. Other studies focus on the combined impact of both components, for example, Kotavaara et al. (2011) for Finland, Holl (2007) for Spain, and Axhausen et al. (2011) for Switzerland. In the subsequent subsections, the focus is placed on studies that analyze accessibility in the specific countries under investigation in this research.

Germany. Accessibility analyzes regarding commuters in Germany in terms of various parameters and form of distance decay functions were conducted by Reggiani et al. (2011a, 2011b). Killer et al. (2011) examined changes in potential accessibility in Germany in the period 1970–2007, also taking into account waiting times at the border between the new and old *Länder*. Reggiani et al. (2011a, 2011b) and Killer et al. (2011) used in their potential models the exponential function with a particular attention to proper estimating the *β* parameter. Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) conducted accessibility analyses using different spatial scales and different accessibility indicators (e.g. BBR, 2005; BBSR, 2011). Schürmann and Spiekermann (2010) studied changes in accessibility to services of general interest by car and public transport in the state of Bavaria. They also developed also accessibility models including potential accessibility for four urban agglomerations in Germany to demonstrate the accessibility patterns over a period of two decades (Schürmann & Spiekermann, 2011). Recently, there have also been analyzes of the impact of the development of high-speed rail in Germany on the reduction of regional disparities in accessibility in this country (e.g. Wenner & Thierstein, 2021).

France. In France, Grasland (2000) and Cattan and Grasland (1997) explored disparities in urban accessibility by contrasting road distances with straight-line (Euclidean) distances. L'Hostis et al. (2004) assessed accessibility in the Nord Pas de Calais region by evaluating the quality of services available to various population groups. Similarly, Bozzani and L'Hostis (2006) examined the benefits of improved accessibility resulting from high-speed rail (TGV) and air transport. Chapelon and Leclerc (2007) analysed ex-ante disparities in rail accessibility in French cities in 2010–2020. In the last decade, papers published by French authors have focused on access to health services (Barlet & Collin, 2010; Barlet et al., 2012; Lucas-Gabrielli & Mangeney, 2020) or analyzed the potential access to jobs at the local level (Claire et al., 2022).

Spain. Spain is the country with the most developed accessibility studies in Europe so far, which is also related to the unprecedented development of transport infrastructure in this country. One of the first comprehensive ex-post evaluations of road accessibility changes in Spain between 1980 and 2000 is the analysis of Holl (2007). The popularity of accessibility studies in Spain occurred in parallel with the Spanish transport master plan 'Plan Estratégico de Infraestructuras y Transporte 2005–2020 PEIT'. The PEIT and its cohesion effects got specific attention in a series of works by López (2007) and López et al. (2006, 2009). In turn, Ortega et al. (2011, 2012) and Lopez et al. (2008) analyzed the cohesion effects of high-speed railway expansion depending on, among others, from different planning levels and different zoning systems. The result of the work of Ortega et al. (2011) was an atlas of road and rail accessibility. The effects of HSR expansion in the context of changes in the level and differentiation of accessibility for the years 1992–2015 were also the subject of research by Monzon et al. (2019). A set of accessibility indicators including location, economic potential and daily accessibility was analyzed as an impact of the high-speed line Madrid-Barcelona-French border by Gutiérrez (2001). From the methodological point of view, cohesion analysis and the impact of distance decay on accessibility results, the works of Condeço-Melhorado et al. (2011; 2014; 2017) are of particular attention. At the regional level, the cohesion effects of high-speed rail development in northern Spain in the context of regional polycentricity were studied by González-González and Nogués (2016). González (2004) used a set of accessibility indicators to evaluate the changes in accessibility in Catalonia in the years of 1985–2000 and related these changes to demographic characteristics of the inhabitants at municipality level. García-Palomares (2000) analyzed the effects of changes in accessibility on the labor market as a result of the construction of a new motorway in the Madrid metropolitan area. In peripheral areas, accessibility in Extremadura was studied by Galán et al. (2002), and accessibility on the Canary Islands using ferry connections and daily accessibility to public administration and commercial activities was analyzed by Hernandez Luis (2002).

Poland. In Poland, numerous studies on accessibility changes have been linked to the rapid expansion of transport infrastructure following the country's accession to the EU. In the Institute of Geography and Spatial Organization of the Polish Academy of Sciences in Warsaw numerous papers have been published on accessibility by individual and public transport at the city level was studied, for example, by Goliszek (2017, 2021); Goliszek and Połom (2016); Stępniak et al. (2019) and conceptual and theoretical works related to a wider application of accessibility at the national level in the form of the use of the Multimodal Accessibility Indicator (Rosik et al., 2017a, 2022a; Komornicki et al., 2018). The examination of shifts in road potential accessibility at the national scale, focusing on both overall accessibility levels and regional disparities, was conducted by Rosik et al. (2015) and Rosik and Stępniak (2015). The Potential Accessibility Dispersion Index was used to analyze changes in territorial cohesion and the role of infrastructure and population accessibility components (Stępniak & Rosik 2016, 2018), as well as changes resulting from individual investments at the international and national level (Stępniak & Rosik, 2013a). In general, at the local and regional level, accessibility studies in Poland differed in terms of the purpose of travel and the attractiveness of destinations, from a wide range of travel destinations at the national level (Stępniak et al., 2013) or access to services of general interest (Stępniak & Rosik, 2013b) to individual travel destinations related to a given travel purpose, e.g. access of rural residents to shops and health care facilities (Taylor, 2003), access to supermarkets (Niedzielski & Kucharski, 2019) and grocery stores (Borowska-Stefańska et al., 2020; Niedzielski, 2021), access of tourists to holiday destinations (Guzik & Kołoś, 2003; Więckowski et al., 2014), access of pupils to secondary education services (Guzik, 2003; Rosik et al., 2021a), job accessibility (Niedzielski & Śleszyński, 2008; Goliszek et al., 2020), health care deserts at the peripheral areas (Rosik et al., 2021b) or access to the airports (Rosik et al., 2017b). The effects of increasing accessibility as a result of infrastructural investments at the regional level were studied by Komornicki et al. (2021) and the effects on the local real estate market were the subject of research by Gadziński and Radzimski (2016), while the impact of changes in accessibility on socio-economic development on the national scale was studied by Rokicki and Stępniak (2018) and Rokicki et al. (2021). The deterioration in the level of accessibility as a result of the flood was analysed by Borowska-Stefańska et al. (2019).

Romania. The number of works on accessibility in Romania is much lower than in the other analyzed countries. A particularly valuable work, where the potential model is used to estimate the accessibility to the network of cities in Romania in 2015, is Rusu et al. (2021). In this paper, attention is drawn to the importance of the correct assessment of the parameters of the potential model in the context of planning policy. Other papers on accessibility in Romania are based on simple accessibility indicators, e.g. the location of tourist services (Bănică & Camară, 2011) or access to the nearest hospital (Dumitrache et al., 2020).

Methods

There are many possible approaches to calculating accessibility which include infrastructure-based, travel cost, cumulative, potential (cf. Bruinsma & Rietveld, 1998; Baradaran & Ramjerdi, 2001; Geurs & Ritsema van Eck, 2001; Geurs & van Wee, 2004) and more methodologically advanced, such as the activity-based approach (Dong et al., 2006). For evaluating long-term accessibility changes at national and regional levels, the potential model serves as an effective approach. Itis frequently employed to illustrate the impacts of transport investments (Gutierrez et al., 2011; Stępniak & Rosik, 2013a) or to assess the outcomes of infrastructure development programs (Holl, 2007; Spiekermann et al., 2015a).

The findings from potential accessibility analyses can provide a basis for a wide range of research endeavors. For example, they can facilitate the examination of regional economic development (Rokicki & Stępniak, 2018) and support analyses of territorial cohesion (Condeço-Melhorado et al., 2011; Stępniak & Rosik, 2016). In equity-related studies, potential accessibility has been applied to assess the equitable distribution of transport services across various population groups (Martens et al., 2012). Additionally, it is a valuable tool for evaluating land-use and transport policies (Geurs et al., 2010), exploring transport disadvantages and social exclusion (Delbosc & Currie, 2011), investigating the connection between population changes and accessibility (Kotavaara et al., 2011), and analyzing the influence of land-use and transport factors on shifts in accessibility (Condeço-Melhorado et al., 2017; Stępniak & Rosik, 2018).

In this paper, we apply the potential accessibility index, which considers all interactions between pairs of transport nodes within countries, factoring in (1) the higher significance of larger centers compared to smaller ones, as measured by population, and (2) the diminishing attractiveness of destinations as travel distance increases (Harris, 1954; Hansen, 1959). The calculation of the intra-regional potential is carried out separately for each of NUTS 3 transport zones based on the self potential formula proposed by Rich (1978) (see also Keeble et al., 1982; Gutiérrez et al., 2011) used for the estimation of the internal road travel time of the area of $NUTS\ 3_i$ (t_{ii}). The transport zone is represented as a circle, with the average travel distance corresponding to half of its radius, $0.5\sqrt{\frac{area}{\pi}}$ and the assumed internal travel speed, $\overline{v_{ii}}$, is 40 km/h (Kotavaara et al., 2011).

As part of the land-use component (Geurs et al., 2010), the variable used in the research was the number of population, which is the variable most often used in studies on accessibility over a longer period of time in the European context (Spiekermann et al., 2015a). As regard to the transport component, we used road travel times as a measure of decay and exponential curve as a function of impedance (Rosik at al., 2015). On the basis of many databases from individual countries, a detailed analysis of the years of construction of individual sections of the road network was prepared. Emphasis has been placed on the motorway network. The primary data source for the road network was the OpenStreetMap (OSM) database (Rosik et al., 2020). The analysis considered four

OSM road categories: motorways, expressways, primary roads, and secondary roads. Additionally, accessibility by car, including the use of ferries, was accounted for to reach all islands classified at the NUTS 3 level within Spain (Balearic Islands) and France (Corsica) in the Mediterranean region. Travel times between nodal cities were determined using the shortest path algorithm. To enhance accuracy, additional penalties for access and egress times were applied (Gutiérrez, 2001), matching the internal travel time.

The potential accessibility indicator for all transport zones is calculated in each of the chosen EU states according to the formula:

$$A_i = POP_i \exp(-\beta t_{ii}) + \Sigma_j POP_j \exp(-\beta t_{ij}) \quad (1)$$

where POP_i and POP_j are the population of NUTS 3 transport zones i and j, respectively, $POP_i \exp(-\beta t_{ii})$ is the value of self-potential of NUTS 3_i (NUTS 2 in Germany), and $\Sigma_j POP_j \exp(-\beta t_{ij})$ stands for the sum of potentials resulting from all other NUTS 3_j in analyzed EU state.

Following Östh et al. (2014) we differentiate the exponential function based on the so-called *half-life* (Stępniak & Rosik, 2018), i.e. the decrease in the attractiveness of the destination to half as the length of the trip increases, using different values of the beta parameter (β). We assume the three travel lengths, i.e. from short trips limiting the attractiveness of travel to half for 30-minute travel time, gradually extending the length of the trip to 60-minutes half-life for which all maps have been prepared, ending with 120 minutes half-life. When calculating the average accessibility for the entire country, the average accessibility of all transport zones is taken into account, weighted by the number of people living in these areas. Therefore, it is the average intra-national accessibility of a resident of a given country, which we refer to as the absolute accessibility of a given country (see formula 2).

$$\overline{A_i} = \frac{\sum A_i POP_i}{\sum POP_i} \quad (2)$$

Study area, transport policies, demographic changes

We have selected five of the six most populous EU states – Germany, France, Spain, Poland and Romania. The research area is 1,955 thousand km^2, which constitutes 46% of the area of the EU. The selection of countries for analyzing long-term changes in accessibility aimed to enable meaningful comparative analysis. The criteria for choosing the countries were as follows:

a) inclusion of at least five countries to assess changes in road infrastructure at the national level;

b) availability of population data at the LAU level from 1960 onward;

c) representing the largest EU countries by population and area;

d) a roughly circular shape to support comparative potential accessibility analysis, which excluded elongated countries like Italy (largest by population) and Sweden and Finland (largest by area).

The overseas regions of France, the French dependent territories, as well as the Spanish Canary Islands and the Spanish enclaves in Africa (Ceuta and Melilla) were excluded from the analysis. However, the islands in the Mediterranean Sea remained, i.e. the Spanish Balearic Islands and French Corsica.

The research area is inhabited by a total of 250 million inhabitants, which constitutes 55% of the population of the EU. The historical population data by LAU are derived from the EUROSTAT project supported by the Directorate-General for Regional and Urban Policy. For 2020, the data source at NUTS level was Eurostat. For the purposes of the paper, the NUTS 3 level of spatial resolution (NUTS 2013; fourth revision) was utilised, except for Germany where it was decided to include units at the NUTS 2 level.

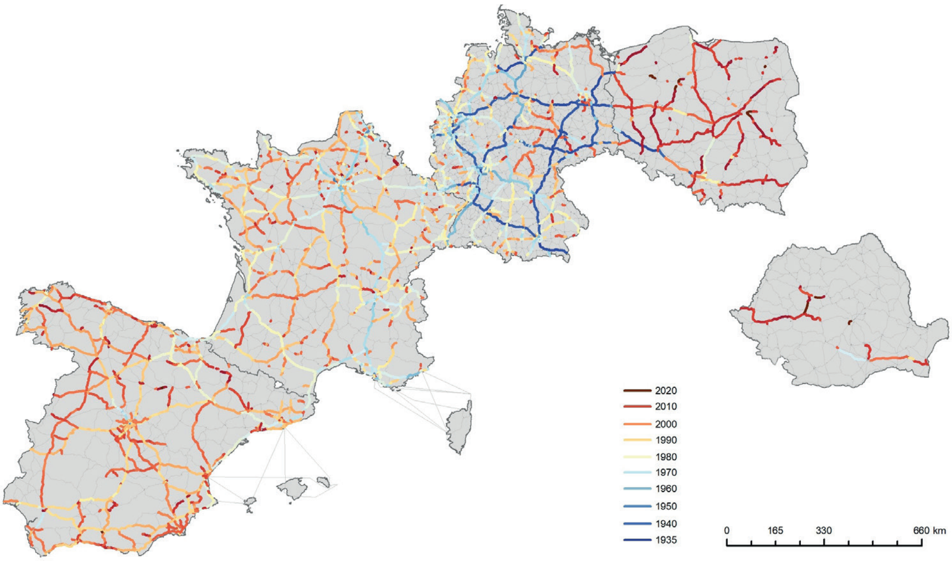

Figure 1. Expansion of the network of expressways and highways in the analyzed countries in the years 1960–2020
Source: own elaboration.

By the year 2020, the motorway network (in various countries referred to as motorways and/ or expressways) in the five countries studied was at different stages of development. The German, French and Spanish networks were close to completion and covered most of their territories, connecting all major urban centres. The Polish and Romanian networks were still in the process of expansion, with the process being more advanced in Poland (see Table 1).

The sequence of the emergence of key sections varied in each country. In Germany, they reflected the country's polycentric settlement network. The system of high-speed routes was artificially divided during the period of the two German states, leading to numerous investments in the 1990s to overhaul the network after reunification. Conversely, the French system resulted from a monocentric settlement network dominated by Paris, with most early motorways built concentrically from the capital. The German and French networks were built with little to no EU funding. In Spain, older investments were mainly for tourism development, particularly along the Mediterranean coast. Madrid remained outside the top-class route network for a long time, and the motorway linking Madrid and Barcelona was only completed in the 1990s. The 'Plan General de Carreteras' (National Road Plan) for Spain was established in 1983 (Holl, 2011). The dense network of routes across the country was mainly constructed with EU funds, including sections through peripheral areas, such as along the border with Portugal.

Table 1. Determinants of motorway network development in the analysed countries 1960–2020

Period	Germany	France	Spain	Poland	Romania
1960–1970	Core network formed before World War II, cut by the Iron Curtain, some sections excluded from traffic	Government plans in response to motorisation, construction of isolated sections	Economic stagnation, few road investments	Road investments do not include motorway routes, road transport is not a priority	Road investments do not include motorway routes, road transport is not a priority
1970–1980	Modernisation and expansion of network in West Germany, stagnation in former GDR	Domination of private investment (BOT system); routes diverging radially from Paris are created, referring to historical routes (pre-18th century routes)	Rapid motorisation, growing demand for infrastructure, investment in tourist regions	Beginning of rapid motorisation, first investments, motorway construction plans based mainly for transit	Slow development of the road network, mainly in the region of the capital, road transport is not a priority; the first plan of the motorway network is created, but apart from small fragments it is not implemented (Fig. 1)
1980–1990		Further development of the network, estimation of too much vehicle traffic, problems in the regulation of toll prices	Implementation of the National Road Plan (and its successor documents); return to the pre-industrial radial route system; use of EU funds	Economic crisis, lack of investment, maintenance of earlier investment plans	
1990–2000	Intensive modernisation plan in the eastern Länder; construction of supplementary sections, network integration	Completion of a multi-centre motorway network, covering sparsely populated areas with the network		Attempts to adapt plans to the new socio-economic situation; few new investments	Post-transformation stagnation, decapitalisation of road network
2000–2010	Completion of the modernisation, then freezing of the intensity of the investment process	Completion of peripheral routes linking radial roads from Paris and Lyon	Shift of the main investment effort in transport from roads to high-speed rail	Utilisation of EU funds; launching of a rapid investment process; concentration on routes connecting Poland with Western Europe	Start of investment process; designation of transport corridors; implementation problems; priority for linking to the Hungarian and thus European network
2010–2020		Limiting the scale of new investments	Decapitalisation of some parts of the network, under-utilisation of some routes	Rapid development of the network based on EU funds; shift towards investments connecting the main cities; realisation of the idea of a network metropolis (National Spatial Development Concept 2020; MRD, 2011)	Construction of several sections using EU funds

Source: own elaboration, based partly on Holl (2011), Fayard et al. (2012), Adamatzky et al. (2017), Komornicki and Goliszek (2023).

The development of the motorway and expressway network in Poland and Romania took place practically only after the accession of these countries to the EU. In Poland, there were previously small sections of routes that were remnants of the German network or built during the centrally planned economy. In Romania, there was one motorway from Bucharest to the Black Sea coast before 1989. In Poland, cohesion policy funding has made it possible to create the foundations of a network system that is similar in nature to the German network (polycentric settlement structure). Initially, the priority was to link up routes from the Western European system, then to include other regional centres. Roads were built in sections, resulting in some incomplete inter-metropolitan relation, including areas near major cities like Warsaw and Krakow. In Romania, the network remains underdeveloped, and the connection to the European system (via Hungary) is still an unrealized priority.

The changes in transport policy (in terms of the development of the motorway network) overlapped with demographic changes. In all countries, there was a gradual concentration of population, followed by depopulation of certain areas (usually peripheral). In West Germany, this process was least evident, facilitated by the polycentric settlement network. However, it became apparent with reunification, when there was a massive outflow of migration from the eastern *Länd*er. Over time, Berlin became an important growth pole again, but the outlying areas of Brandenburg and Mecklenburg continued to experience depopulation. In France, the outflow of population mainly affected areas of the Massif Central and already took place in the 1960s and 1970s. Over time, it also extended to the northern districts of the country. At the same time, emigration also took place from peripheral areas of Spain (Andalusia, Estramadura, Galicia). While in Germany and France these were mainly internal migrations, in Spain there was also an outflow to other countries (including France and Germany). In Poland and Romania, migration processes were partially frozen by regulations of the centrally planned economy before 1990 (e.g. restrictions on free settlement in Warsaw; cf. Węcławowicz, 2002). Even then, however, there was a gradual exodus of people from rural to urban areas in both countries. After the system transformation, these processes accelerated significantly. In addition, after accession to the EU and the opening of labour markets, there were very large migration flows to Western Europe. Their scale was relatively somewhat smaller in Poland than in Romania (Velasco Echeverria et al., 2022). In most of the countries analysed (except Romania), there was also an inflow of external migrants in particular periods. In the first decades, this was mainly the case for Germany (migrants from Turkey) and France (migrants from North Africa and former colonies), later also for Spain (migrants from Africa) and between 2010 and 2020 also for Poland (migrants from Ukraine). However, external inflows generally did not balance internal concentration processes. Migrants directed themselves to the largest metropolises of the respective countries.

Results

During the analyzed period, changes in accessibility in the group of five countries resulted from changes in population number, its distribution and infrastructure activities. The largest changes in percentage terms concerned Spain (apart from the two decades of the 1980s and 2010–2020 of investment slowdown) and France.

In Spain, there was a turn in terms of stimulating the increase in accessibility for short trips - this type of travel was particularly preferred in the 1960s, mainly due to numerous investments in highly urbanized areas, in growth centers, in Madrid and Catalonia, and in the following decades investments connecting large centers and stimulating the increase in accessibility for long journeys have become more important, especially in the years 1980–2010, accessibility was growing at a rapid pace for long journeys (*half-life* = 120 minutes). This may be the result of investments in the south and west of the country. These areas are less well equipped with infrastructure, e.g. in Andalusia. In the last analyzed decade, 2010–2020, accessibility changes are again higher for short trips than for long trips. The reason may be the fact that there are fewer investments and they are again concentrated, as in the 1960s, in the most important centers, mainly in the north-eastern part of the country (Fig. 2, 3 and 4).

In France, we do not observe a significantly greater increase in accessibility for shorter or longer trips in any of the decades studied. The investments successively covered the entire territory of the country, including areas where no strong population growth was observed (e.g. Massif Central or Brittany). In turn, after 1990, accessibility changes were lower, but again they concerned sparsely populated areas. Interestingly, and requiring further research on the relationship between infrastructure development and migration, areas located in the west of France, on the Atlantic Ocean, significantly improved their accessibility in the years 1960–2000, and in the following decades these areas saw a significant increase in the number of inhabitants, despite the lack of further major investments (Fig. 2, 3 and 4).

In Germany, higher-class road infrastructure was developed mainly before the analyzed period, so in percentage terms the changes in accessibility were no longer that high (apart from the first decade of the 1960s). In the first decade of the 2000s there are basically no changes, with a paralel slight decline in the number inhabitants of Germany during this period. As in France, there were no major differences between changes in accessibility for short or long trips. After 1990, the very intensive development of road infrastructure in the former East Germany (modernization of pre-World War II highways, launch of routes crossing the Iron Curtain and construction from scratch of several missing sections) counteracted the decline in the population of these areas, as a result of which the accessibility of East Germany did not decrease significantly compared to other areas of the country. Improving accessibility in German regions is not as insular as in France. The development of infrastructure began in Germany earlier and therefore the process after 1960 has been more harmonious in its spatial arrangement (Fig. 2, 3 and 4).

In Poland and Romania, positive changes in accessibility in the first three decades of 1960–1990 were mainly due to population growth. The collapse in population growth after 1990 also resulted in a reduced growth rate (in Poland) or a decline in the level of accessibility (in Romania) in these countries. The beginning of road infrastructure development after 1990 did not result in a significant improvement in accessibility. This was due to: a) simultaneous demographic processes; b) chaotic road investments, often politically driven, without ex-ante analyzes indicating their effectiveness in improving accessibility; c) continuation of transport policies from the period of the centrally planned economy (dominance of transit purposes, especially east-west routes).

In Poland, spatial changes in the population number consisted largely in the concentration of inhabitants in several metropolises, as well as in the long-term depopulation of some peripheral areas. Both of these processes have accelerated in recent decades, and in the last decade of 2010–2020 there was an additional investment rebound thanks to an unprecedented big push in road infrastructure and the use of EU funds (Rosik et al., 2015). Many of these investments were located in peripheral areas, including: in north-western Poland or in the east of the country, which resulted in a decrease in regional differences in accessibility. In other words, similarly to Germany, the expansion of infrastructure resulted in improved accessibility of depopulated peripheral areas. It thus balanced the demographic decline (Fig. 2, 3 and 4).

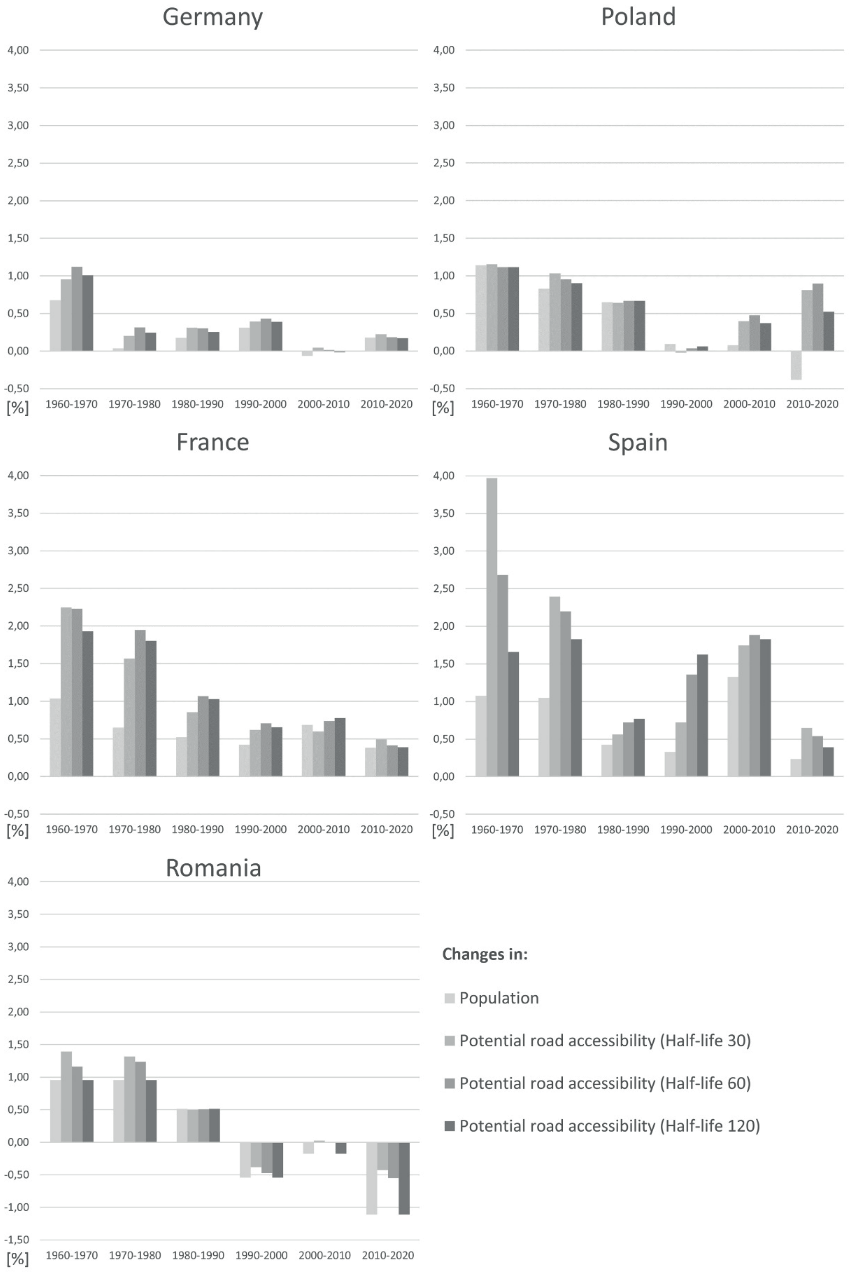

Figure 2. Average annual changes in population and potential road accessibility for Germany, France, Spain, Poland and Romania for the six decades 1960–2020 (trip length for *half-life* = 30, 60 and 120 minutes)
Source: own elaboration.

In Romania, the population decline was so great that a relatively small number of investments in new sections of motorways and expressways in the decade 2010–2020 did not result in an improvement in the accessibility situation. Moreover, the longer the journey, the highest accessibility declines. Only some areas, such as the Romanian-Hungarian border or the Black Sea coast, gained accessibility thanks to new motorway sections (Fig. 2, 3 and 4).

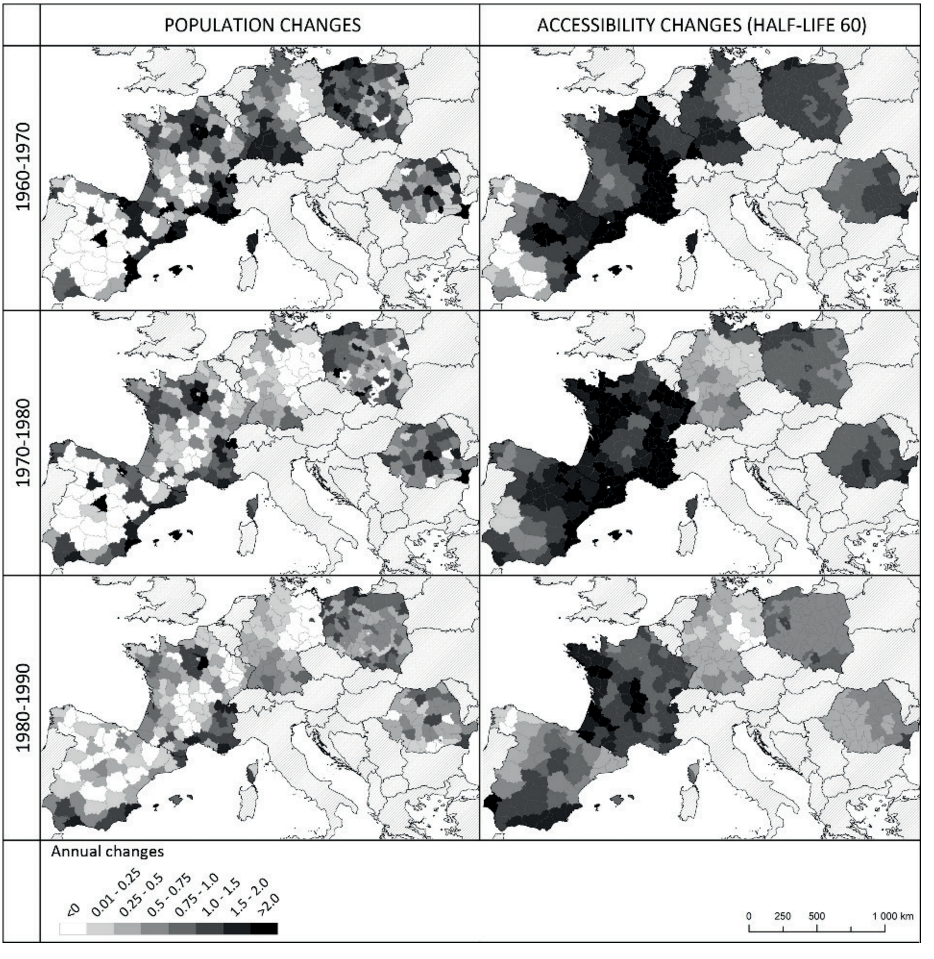

Figure 3. Average annual changes in population and the level of intra-national regional road accessibility in Germany, France, Spain, Poland and Romania in three decades in the period 1960–1990
Source: own elaboration.

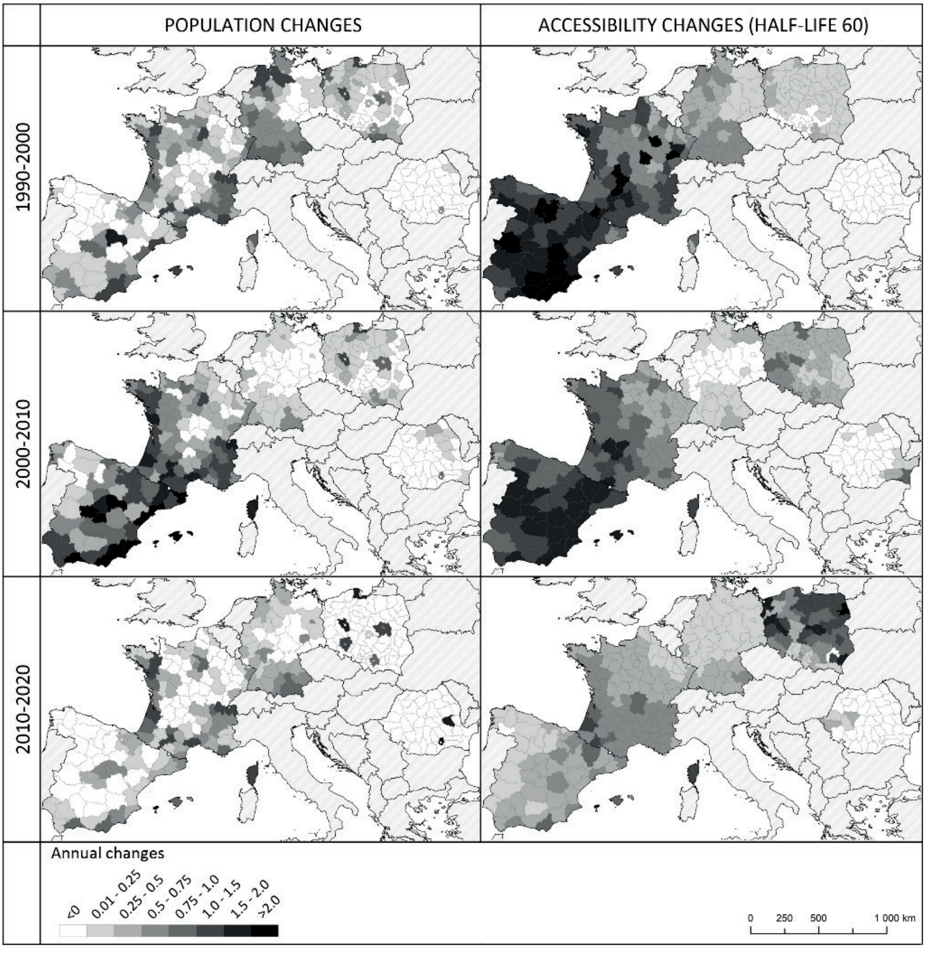

Figure 4. Average annual changes in population and the level of intra-national regional road accessibility in Germany, France, Spain, Poland and Romania in three decades in the period 1990–2020
Source: own elaboration.

Discussion and conclusions

The results obtained confirm that changes in the level of accessibility in the largest European countries are the result of three main factors:

a. (a) the underlying layout of the settlement network and the distribution of the population;
b) ongoing demographic processes, especially migration;
c) the transport policy implemented.

At the threshold of the period under study, only Germany (among the selected countries) had a developed motorway network. Therefore, the increase in accessibility in Germany was due to demographic growth. Paradoxically, a similar situation existed at the time in Poland and Romania, where the motorway network was almost non-existent and road infrastructure did not play a significant role in transport. In the following decades, all the other countries undertook road investments as a result of growing demand, much of it caused by fast motorisation, or an inflow of tourists (Spain) or expected and then actual transit (Poland). Over time, adaptation to the changing geopolitical situation (investments in East Germany, 'linking' to Europe in Poland and Romania) began to play an increasing role in the transport policy of these countries, as well as that of the EU. The objectives of regional development and support for peripheral areas were also emphasised in the adopted network expansion plans, but were mostly implemented further down the line. Motorway networks did, however, cover entire areas of Germany, France and Spain and almost all of Poland. However, this did not prevent demographic changes. This is particularly evident in the earlier decades in northern France and later in northern Spain and eastern Poland. Road investments, due to their large scale, resulted in improved accessibility despite demographic losses. However, they did not translate into stopping the outflow of migration. At most, one can speculate that they slowed down the outflow. Thus, the dynamics of changes in accessibility indicators show that the development of the road network can, up to a certain point, 'balance' migration losses. However, the possibilities for such balancing are limited. They are only observed in periods of major investment booms (e.g. Poland 2010–2020, Spain 1990–2000, France 1970–1980). Where the outflow of population is massive, the effects of large-scale investments produce only small improvements in accessibility (e.g. East Germany in the period 1990–2000). If their scale is limited accessibility rates fall (Romania).

The analysis also gives rise to the hypothesis that the creation of a motorway network that also covers peripheral areas may, in the long term, be helpful in reversing negative demographic trends. This would be indicated by population growth in western France (Atlantic coast) and some centres in eastern Germany. Most probably, a good road network there was one of the important preconditions for breaking the negative demographic trends. However, it was not the only condition. This is confirmed by observations from areas where investments mainly served international relations and transit (e.g. the western borderlands of Poland and Romania, the area concentrically surrounding Madrid in Spain). In the absence of other endogenous development factors, even a spectacular improvement in accessibility had no effect on the migration balance there. However, effects of this kind can be delayed and thus require in-depth research in the future. The case of Spain, may also prove that depopulation can lead to a situation where investment in peripheral areas should be considered to be scaled up (Holl, 2011).

The study also shows that the demographic component should be an important consideration for transport policy, influencing the evaluation of planned investment activities. The processes taking place in the development of the network may change the distribution of demographic potential (depopulation, suburbanisation, return of settlement attractiveness). One factor in these changes is the level of accessibility polarisation of the examined units. This polarisation increases during an intensive investment process. There are always some regions that benefit more from it, and it is only when all territories (including peripheral areas) are covered by a road network that the disproportions are reduced again. Even then, however, polarisation may increase as a result of migration movements alone (with an unchanged transport network).

An important direction for extending the model presented in this paper is to enhance the regional typology by incorporating the potential negative effects of the transportation component on accessibility, as discussed in the literature on vulnerability and resilience (Jenelius et al., 2006; Wiśniewski et al., 2020). Additionally, a significant methodological refinement that also addresses some of the model's limitations involves increasing the spatial resolution to the LAU level, following the approach employed by Spiekermann et al. (2015a, 2015b). This distinction could be further developed to encompass the influence of settlement systems –such as their degree of centralization and polycentricity—on the efficiency of transport and settlement structures (Śleszyński, 2021) within the framework of potential accessibility convergence (Rosik et al., 2025a).

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