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# From improvements in accessibility to the impact on territorial cohesion: the spatial approach

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**Abstract:** During the last decade, Poland has experienced a big push in road network development. As a result, the fundamentals of the modern road network have been established. This paper aims to recognize the consequences of changes in accessibility for territorial cohesion, analyzed simultaneously in national and international dimensions. The results provided show that similar spatial patterns and the overall scale of improvement in accessibility lead to entirely different impacts on the level of territorial cohesion. From the international perspective, the investments implemented have a strong positive cohesion impact, while from the national perspective a slight increase in regional polarization has been produced. Moreover, there was an adverse effect on territorial cohesion for almost 40 percent of Polish municipalities, depending on whether or not we include international destinations. The fact that analyses conducted in the national and international dimension yielded opposite results supports the presented approach of a multidimensional evaluation of transport network development.

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## 1 Introduction

Contemporary Poland is a real laboratory for the analysis of accessibility. During the last decade, the total length of the motorway network has increased dramatically from a mere few hundred kilometers to more than 3000 kilometers. The Polish "big push" for roads coincided with the country's accession to the European Union (EU) in 2004 and the acquisition of access to European funds. The overlap between the two EU programming periods creates favorable circumstances for summarizing the changes in accessibility during the period of 2004–2013.

Accessibility implies a potential for different kinds of interaction: mobility, including commuting (Holly 1993) or migration (Spiekermann and Neubauer 2002; Kotavaara et al. 2012); capital flows (Bröcker, Korzhenevych, and Schürmann 2010); or potential production (Condeço-Melhorado, Martín, and Gutiérrez 2011; Yu et al. 2013). Aschauer (1989) proved that there is a strong link between transport infrastructure and economic growth. Moreover, the growth resulting from infrastructure investment in one region is noticed also in its neighboring regions due to the "spillover effect" (Condeço-Melhorado et al. 2014; Pereira and Roca-Sagalés 2003).


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Further, the highest economic returns are observed in the provinces directly connected to the central region (Yu et al. 2013). This conclusion is in line with the asymmetrical distribution of the improvements in potential accessibility among the regions as a consequence of the development of transport infrastructure (Gutiérrez, Condeço-Melhorado, and Martín 2010). The construction of a new motorway to poorly developed (in terms of accessibility) regions from well-developed (i.e., more accessible) regions produces more significant improvements in accessibility in the former than in the latter regions.

However, the relationship between new motorway investments and the reduction of disparities in accessibility is much more complex, especially when they connect regions with the same degree of accessibility (Gutiérrez et al. 2011; Ortega, López, and Monzón 2012; Stepniak and Rosik 2013). The situation is even more complicated when evaluating large-scale transport infrastructure programs (López, Gutiérrez, and Gómez 2008).

Moreover, the evaluation of a transport investment can be treated as a complex interplay between investment efficiency (i.e., improvement of overall accessibility) and its impact on regional disparities. The interplay is partly a consequence of the aims of European TEN-T projects: on one hand, transport network efficiency leading to more dynamic economic growth (Sichelschmidt 1999) and, on the other hand, territorial cohesion (CEC 2009), which is understood as fewer regional disparities and more balanced development (CEC 2004).

Although the importance of cohesion policy has been growing since the 1980s, at the beginning it was limited to social and economic issues. Nevertheless, since the Third Cohesion Report, cohesion policy has become more territorialized and territorial cohesion has become one of the primary goals of European Community (CEC 2004), emphasizing the role of accessibility and transport infrastructure development for inhibiting regional disparities (CEC 2006). An in-depth review of the relationship between transport infrastructure development and territorial cohesion is provided elsewhere (Condeço-Melhorado, Martín, and Gutiérrez 2011), and it is not our intention to repeat this work.

Polish national policy has followed the evaluation of European policy goals. The recent strategy of transport infrastructure development (TDS 2013) is grounded not only in the evaluation of investment efficiency (i.e., accessibility improvements), but also in the assessment of territorial cohesion impact. Moreover, in recent studies evaluating Polish transport investments, a multidimensional approach has been adopted, assessing investment priorities from national as well as international (i.e., European) points of view (Komornicki et al. 2013).

The territorially imbalanced provision of the accessibility level may contribute to social segregation and the exclusion of inhabitants in less-favored regions, which in turn hampers social and territorial cohesion as well as regional or even national competitiveness. Thus, the discussion about the reduction of regional disparities is not limited to the question of equality or justice anymore. It combines issues of justice and equality as well as regional sustainable development and economic growth and competitiveness. As a result, a proper evaluation should include both aspects relating to the improvement of accessibility: investment efficiency and an equity target.

Furthermore, an important set of questions is related to the spatial pattern of the impact of developments in the road network. Firstly, to what extent do particular municipalities gain from the development of transport infrastructure in terms of improvement in potential accessibility, and what is a spatial pattern of this improvement? Secondly, what is the relationship between locally based changes in accessibility and overall changes in the level of territorial cohesion? What kind of changes lead toward an increase in regional polarization and which of them diminish regional differentiation? Where are these changes located?

Finally, the impact of the particular road development program depends on whether a national or an international perspective is adopted. A peripherally located road segment has rather limited impor-

tance for the national road network; however, it can be simultaneously crucial for international connections. On the other hand, while a centrally located road segment connecting important national centers may be decisive for national flows, its significance for international connections may be only illusory. Thus, the comprehensive evaluation of a road network development program should include national as well as international dimensions. While the results obtained separately for particular dimensions deliver important information about the impact of transport network development (e.g., its scale and spatial pattern) from selected points of view (i.e., national or international), the comparison of the results should provide indications concerning the future direction of regional development.

As a result, national and international aspects of evaluation of infrastructure investments should be treated as complementary. The relevance of international (European) territorial cohesion, in particular in Eastern European countries, has been clearly proved in the Cohesion Reports of the European Commission. On the other hand, intranational cohesion is needed because some western and northern regions are behind central Poland in both infrastructure and socio-economic terms. Moreover, the dedicated Operational Program (Development of Eastern Poland) was established to support the development of the less-favored region of Poland.

In conclusion, the main research questions are as follows: what are the changes in overall accessibility and levels of territorial cohesion from both the national and international perspective, and what are the spatial patterns of these changes? To what extent may the improvement in accessibility be defined as a factor promoting or inhibiting cohesion, and is there a regular trend in the spatial pattern of municipalities affected by a particular direction of impact on territorial cohesion? What are the differences between the results from both perspectives and where are these differences produced? The results of empirical analysis are presented at a very detailed spatial scale (Polish municipalities, LAU-2 units) and the analysis covers the years 2004–2013.

## 2 Methods

In this study, accessibility is understood according to Hansen's classical definition—the potential for interaction (Hansen 1959)—and it is calculated using the potential accessibility indicator. The indicator uses the relationships between all pairs of nodes in the network, assuming an impedance form in these relations resulting from a greater impact of larger centers than smaller ones and a diminishing importance of more distantly located destinations (Hansen 1959). We chose time as a distance decay element, the negative exponential function as an impedance form (cf. De Vries, Nijkamp, and Rietveld 2009; Kwan 1998; Reggiani, Bucci, and Russo 2010), and population as a proxy of destination attractiveness. The population size of a destination municipality is assumed to be positively correlated to the level of potential for human interaction and indirectly correlated to the level of economic activity, services provision, etc.

The indicator consists of three separate components: self-potential (i.e., the level of accessibility produced by the region itself), internal potential (i.e., national, resulting from the opportunity to access all other Polish municipalities), and external potential (i.e., international, as an effect of reaching destinations all over the European continent) (Tóth and Kincses 2011). In addition, self-potential is estimated using the radius of a circle equaling the area of the municipality for an approximation of the internal travel impedance (Rich 1978). The last two components are based on the shortest travel time between origin and destination nodes, supplemented by a time penalty for entering and leaving the respective spatial units. The penalties are equivalent to half of the internal travel time of the respective units (cf. Gutiérrez et al. 2011). Travel times between nodes representing municipalities are calculated based on the maximum speeds for a private car on the respective category of road derived from the Polish Highway Code and then adjusted downward based on impediments to driving such as built-up

areas, topography, and population density (Rosik 2012). In the international dimension, the time penalties at the external borders of the Schengen area are estimated for particular border crossings based on the average data for the period 2010–2011 provided by the Polish Border Guard. They vary from 30 to 150 minutes.

Although the state border may influence the intensity of spatial interactions between the origin and destination (Rietveld 2012; Nitsch 2000), there is a substantial lack of empirical data concerning traffic flows at specific Polish borders (e.g., Schengen versus non-Schengen borders). In consequence, two extreme cases are under investigation: the national dimension, with Polish municipalities absolutely separated from external destinations, and the international dimension. In the latter, the border effect is limited to a time penalty at non-Schengen borders (cf. Spiekermann et al. 2013).

The applied travel time matrices consist of all Polish municipalities used as origin and destination zones, supplemented by the additional 212 transport zones from all over Europe. Following the approach proposed by Schürmann and Talaat (2000), the scale of the latter units is negatively correlated to the distance from the national external border.

In general, the variation of the parameters of the distance decay function affects neither spillovers nor the general distribution of changes in accessibility among regions, although a greater exponent produces higher regional differentiation as well as more limited spillover effects (Condeço-Melhorado, Gutiérrez, and García-Palomares 2013). In other words, the distance decay function influences the overall scale of changes but not its pattern (Stepniak and Rosik 2013). In the research presented here, we concentrate on the spatial characteristics of change in accessibility rather than on its scale. Thus, the distance decay function should be realistic, but it is not decisive.

There exists a large body of literature in the field of potential accessibility analyses, which varies according to the spatial scale of analysis (regional, national, or international), estimates of travel purpose, and social perception of distances. In consequence, one can find a wide range of $\beta$ parameters used in particular studies. They range from 0.003 for a European scale analysis of freight transport (Schürmann and Talaat 2000) to 0.289 in the case of medical general practitioners' surgeries at a regional scale (Haynes, Lovett, and Sünnenberg 2003). In our study, we follow the idea presented by Spiekermann et al. (2013) that the value of the $\beta$ parameter should be acquired at a median travel time typical for a specific travel purpose or type. Therefore, we adopt $\beta$ parameter that equals 0.005776 for the international dimension and 0.013862 for the national dimension. The former is in line with the average time of tourist and business trips and the latter with the average commuting trip in Poland (KMR 2008; Warsaw Traffic Survey 2005). Calculations of potential accessibility indicators were made in the OGAM application (Pomianowski 2012).

The usual approach in the evaluation of infrastructure development is the comparison of levels of accessibility in scenarios before and after an investment, regardless of whether the evaluation concerns that particular investment (e.g., Gutiérrez et al. 2011; Ortega, López, and Monzón 2012) or the whole infrastructure development program (e.g., Condeço-Melhorado, Martín, and Gutiérrez 2011; Holl 2007). In our case, the baseline scenario includes the state of the road network at the starting point of our analysis (in 2004), while the final scenario assumes the state of the road network at the end of the contemporary European financial perspective (at the end of 2015, based on the "n+2 rule" arising from the annual allocation provided in the programming period 2007–2013). To extract the change in accessibility resulting directly from the development of the road network, we use the ceteris paribus approach—i.e., we assume that all other factors that may have an impact on the results obtained are constant, such as road development in neighboring countries, demographic changes, and the role of state borders. In order to assure a ceteris paribus comparability of the results, we assume that the division between Schengen and non-Schengen borders is constant from 2004–2015, even though Poland and

other new EU member countries implemented the Schengen Agreement in December 2007. Therefore, in this study the border regimes before 2007 remain the same as at the end of 2007.

The research presented focuses on accessibility changes and changes in the level of territorial cohesion. We rely on two indicators that are directly related to the potential accessibility indicator. The first one is used to assess investment efficiency. It describes the overall (at national level) scale of improvement in accessibility. The overall accessibility effect is calculated as the population-weighted average change in the level of accessibility at a national scale between the baseline and final scenarios. The second indicator is based on the coefficient variation of accessibility values. The Accessibility Dispersion (AD) index is used to evaluate the impact of the development of the road network on the level of territorial cohesion (López, Gutiérrez, and Gómez 2008; Ortega, López, and Monzón 2012). Higher AD values mean a more polarized distribution of accessibility. Therefore, an increase of values of the indicator demonstrates an increase in polarization.

The study concentrates on differences in accessibility patterns between the national and international dimensions; thus, we measure the accessibility indicator in both dimensions and at two points in time (in the year 2004 and 2013+2). Therefore, our approach includes two-fold comparisons: between scenarios (before versus after) and between spatial dimensions (international versus national).

The following part of the paper consists of the empirical results of the analyses conducted. It starts with a description of the baseline scenario for both dimensions (national and international), supplemented by a description of road investments implemented during the study period. Then, the evaluation of the overall improvement in accessibility and changes in the level of territorial cohesion during the years 2004–2013 is presented. This is followed by an analysis of the regional differentiation of the impact resulting from road development in the period 2004–2013 that leads to a regional typology of Polish municipalities. The final section discusses the implications of the findings in light of the main research questions.

## 3 Background information

The aim of presenting Figure 1 is to demonstrate and compare the baseline potential accessibility values for both dimensions investigated. The national scale of analysis shows the existence of two main poles of higher accessibility levels: one located around Warsaw (especially in a southwesterly direction) and the second containing the Cracow and Upper Silesia conurbations. Moreover, the arc of higher accessibility values that connects both of these poles is also clearly visible. The influence of other metropolitan areas is rather limited, mainly due to the limited state of development of the road network in 2004. The lowest accessibility values are noted in the northwestern periphery of Poland and along the eastern border.

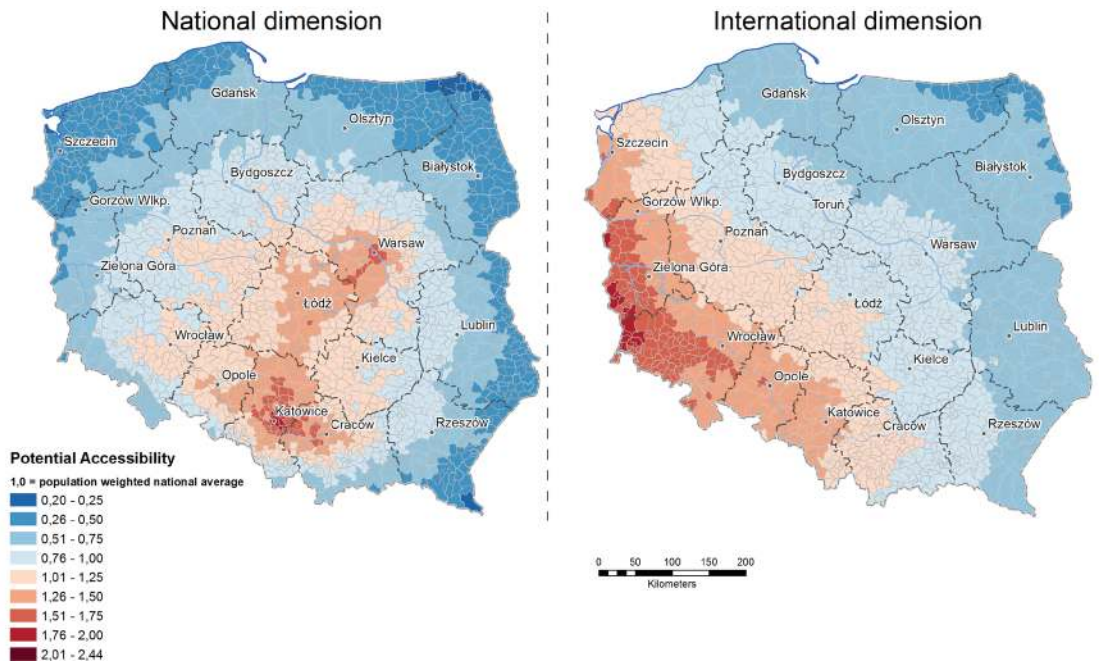


**Figure 1:** National versus international dimension: baseline scenario (2004)

In opposition to this, the impact of Polish metropolitan areas is almost unnoticeable in the international dimension, in contrast to the great influence of destinations located outside the western and southern borders, which is clearly visible (Figure 1). Nevertheless, lower accessibility values are similarly noted on the northeastern periphery of the country and, to some extent, along the eastern border of the country, which is related to the clearly visible negative impact of the waiting time on non-Schengen borders.

During the years 2004–2013+2, a big push to improve the Polish road network was observed. From a mere few hundred kilometers of separate, unconnected motorway segments, the fundamentals of the modern road network were established. Due to the investments implemented, the central part of the country (specifically in the Warsaw and Łódź metropolitan areas) has gained high-speed connections with the northern (to the Gdańsk Metropolitan Area by the A1 motorway), eastern (to Poznań and further to Berlin by the A2 motorway), and the southeastern (to Wrocław by the S8 express road) parts of the country (Figure 2). Moreover, the whole southern part of Poland as well as the German and Ukrainian borders have been interlinked via the A4 motorway. Nevertheless, there are still areas that are only slightly affected by the national road development program, especially in the eastern, less-accessible part of the country. The remaining questions are then what is the impact of this "investment negligence" on the spatial pattern of improvement in accessibility, and how does it affect territorial cohesion? The next section is dedicated to these issues.

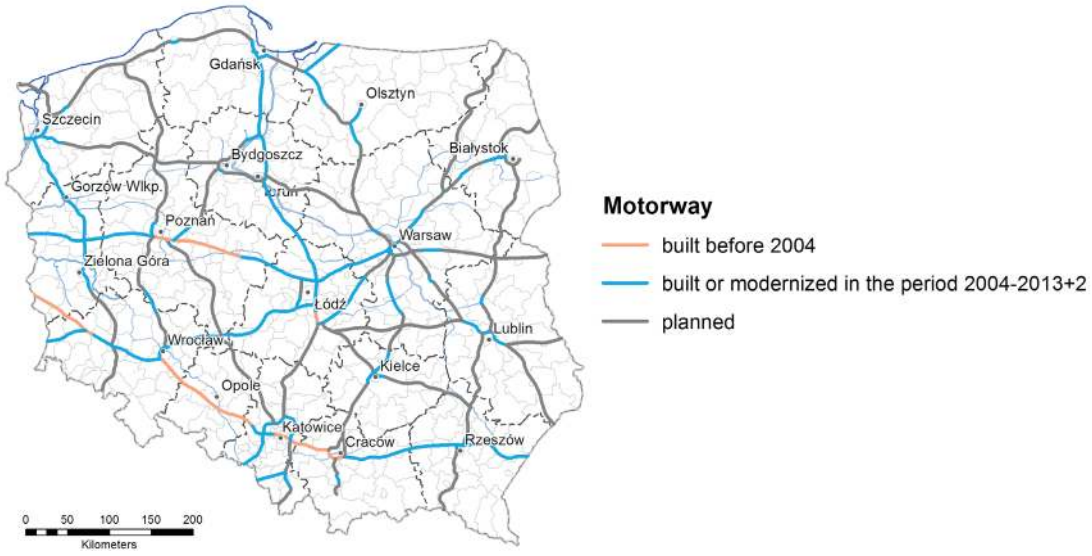


**Figure 2:** Development of the road network in Poland: 2004-2013+2

## 4 Results

Table 1 highlights the considerable impact of the development of the road network on the overall change in accessibility levels. Regardless of the dimension of the analysis, during the last decade the increase in potential accessibility values exceeds 20 percent, with slightly higher growth for the national dimension. The spatial distribution of accessibility improvements is also quite similar in both the dimensions analyzed (Figure 3). The most important changes are visible in the center of the country and along the transport corridors that have been built or modernized. The differences between the results received for both dimensions are mainly caused by the adoption of two different β parameters. If the lower β parameter is used, the territorial impact of investment in transport infrastructure (the so-called "spillover effect") reaches out to more distant areas. Simultaneously, the overall change in accessibility is higher. Therefore, in the national dimension, the improvement in accessibility is more polarized and the municipalities most affected by an increase in accessibility potential are particularly concentrated along the new segments of motorway (i.e., newly-built or modernized).

**Table 1:** Improvements in accessibility and territorial cohesion

| | | **Improvement in accessibility** | | | | **Level of territorial cohesion (AD)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **2004** | **2013+2** | **Change** | | **2004** | **2013+2** | **Change** | |
| | | | | Absolute | Relative 2004=100% | | | Absolute | Relative 2004=100% |
| **Dimension** | **International** | 25,157 | 30,388 | 5,230 | 120.79% | 0.299 | 0.253 | -0.046 | -15.31% |
| | **National** | 2,748 | 3,383 | 635 | 123.12% | 0.385 | 0.387 | 0.002 | 0.44% |

Surprisingly, the results of the evaluation of change in territorial cohesion show very strong variation, depending on whether or not we include international destinations. In the former case, the changes noted clearly lead to a more homogenous spatial distribution of accessibility, while in the latter case they lead to a slightly higher level of polarization (Table 1). These differences may be explained by the confrontation between the spatial distribution of the improvement in accessibility (Figure 3) and the spatial differentiation of baseline accessibility values (Figure 1).

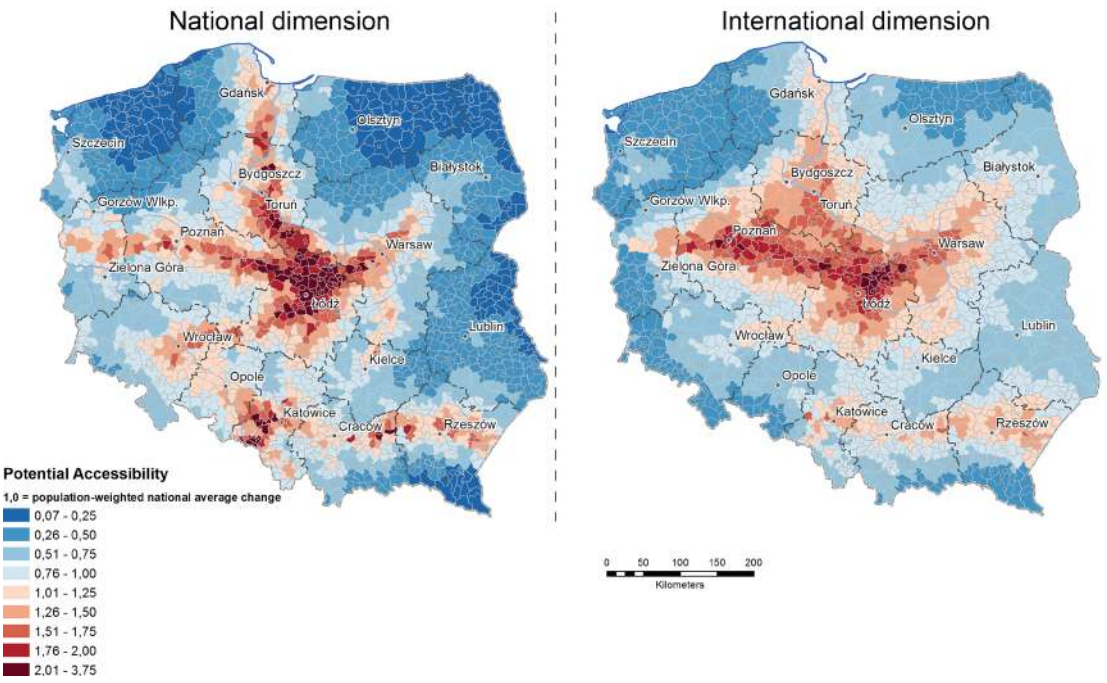


**Figure 3:** The national versus the international dimension: absolute change in potential accessibility (2004–2013+2)

The comparative analysis of the aforementioned factors leads us to the answer to the question about where the improvement in accessibility produces an increase in the level of territorial cohesion and where it leads to more polarized space. In general, there are two different conditions that provide more sustainable territory (in terms of accessibility): an above-average increase in accessibility values noted in municipalities characterized by a relatively low level of accessibility and a below-average increase in accessibility in the relatively highly accessible areas. By contrast, two opposite trends in the increase in accessibility and baseline accessibility levels lead to further polarization.

On the basis of the aforementioned assumptions, two regional typologies are prepared separately for the national and international dimensions (Figure 4). In the national dimension, both the periphery and central area of the country are affected by an accessibility change that produces a higher level of polarization. Simultaneously, there are some limited, in-the-middle core areas that are affected by a low increase in accessibility that in consequence diminishes regional differentiation. Moreover, change promoting cohesion (pro-cohesion change) is also observed within the corridor-shaped areas, located peripherally along the most significant transport investments—i.e., the northern part of the A1 motorway, the western part of the A2 motorway, and the eastern section of the A4 motorway.

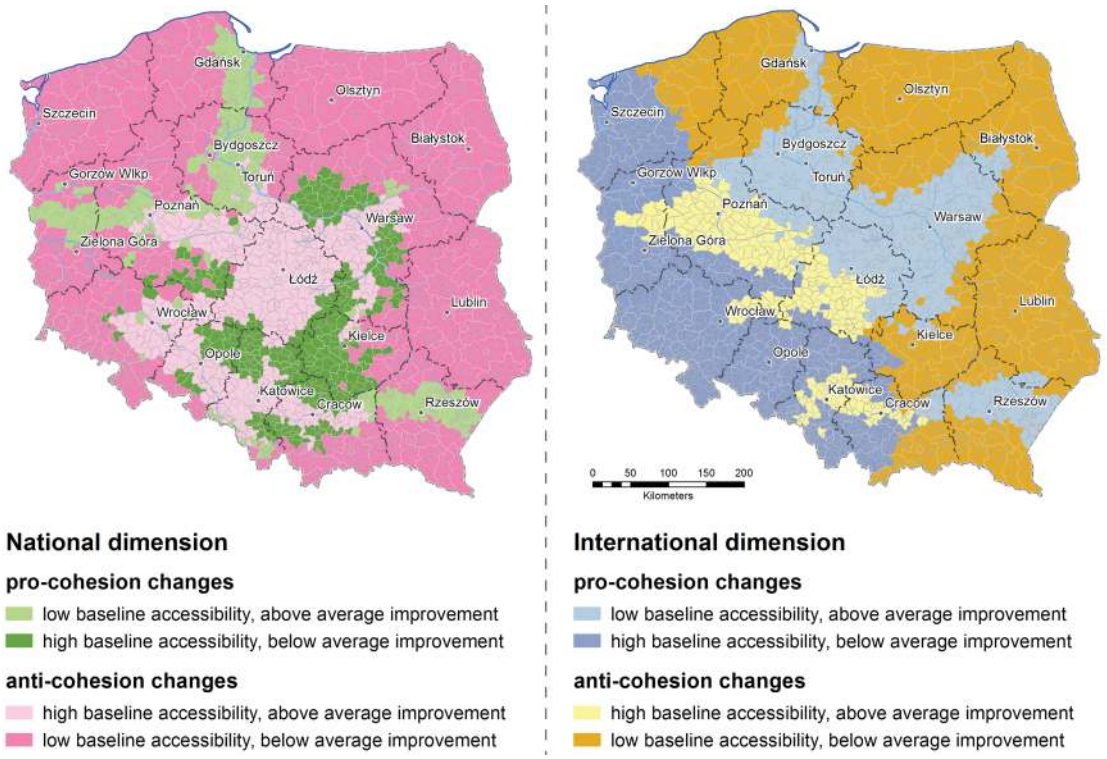


**Figure 4:** Regional typology: pro-cohesion versus anti-cohesion changes in the national and international dimension

In case of the international dimension, the pattern is less of a mosaic. Changes described as anti-cohesion affect the eastern and northern part of the country—i.e., the areas that are characterized both by poor accessibility and an insufficient improvement in accessibility. The impact of transport investments producing a reduction in cohesion is also observed in the more accessible areas that gain new motorways or express roads, such as the territory between the Polish-German border; Poznań, Łódź, and Wrocław; and between Katowice and Cracow. The pro-cohesion changes are observed along the western and southwestern borders as a result of a lack of significant new links to the European core in this more accessible part of the country. The pro-cohesion effect, which is found in the center of Poland and in the vicinity of the eastern section of the A4 motorway, results from new investments that improve international accessibility.

The comparison of the two typologies enables the researcher to answer the question about where the differences in the impact of the accessibility improvement on the level of territorial cohesion at national and international scales are produced. The positive, pro-cohesion effects of transport policies in terms of both the national and international context are observed along northern sections of the A1 motorway and eastern sections of the A4 motorway. These are exceptionally long sections built in areas with relatively low accessibility from both the national and international perspectives.

On the other hand, the insufficient scale of road investments in the less accessible eastern margin and in the majority of the northern periphery of the country produces an anti-cohesion effect regardless of the dimension of analysis (Figure 5). The same small scale of investment affects the western borderland, although in this case it produces anti-cohesion changes at the national level and pro-cohesion changes in the international dimension. The former is related to the peripheral location of the area from the national perspective and, in consequence, to a low baseline accessibility level, while the latter is

linked to its relatively good connections to the densely populated areas across the border, including the Berlin area, Saxony, and the northern Czech Republic.

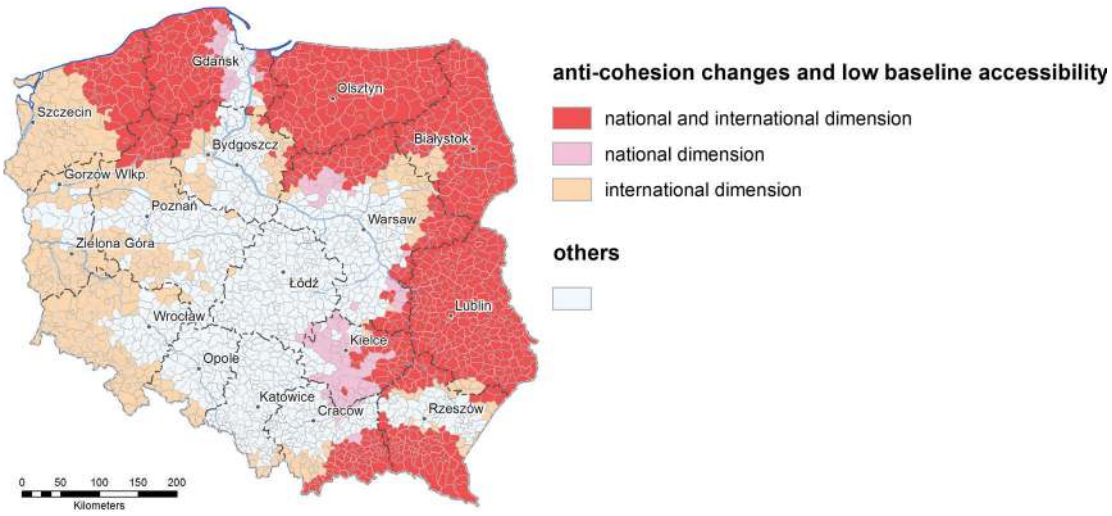


**Figure 5:** Delimitation of unfavored regions in terms of accessibility level and territorial cohesion change

## 5 Conclusions

In this paper, we analyzed the changes in accessibility that resulted from the program for the development of the road network in Poland from 2004–2013+2. We applied a two-dimensional approach that combined the national and international perspectives. The research focused on the consequences of changes in accessibility for territorial cohesion. Our research introduced the spatial perspective of the relationship between improvement in accessibility and territorial cohesion. As a result, we provided empirical evidence of the variation between municipalities in terms of the scale of improvement in accessibility and the direction of the impact on territorial cohesion (i.e., pro- or anti-cohesion impact). At the regional level, the analysis presented shows that the accessibility improvement and territorial cohesion impact resulting from the transport investment should be investigated independently, since there is no direct relationship between both issues. It means that improvement in accessibility should not be defined as a direct factor promoting or inhibiting cohesion.

Although the spatial pattern of the overall improvement in accessibility is quite similar in both dimensions (national and international), its impact on the level of territorial cohesion is entirely different. While from the international perspective the 2004–2013+2 investments have clearly led to a more even spatial distribution of accessibility, a slight increase in regional polarization has been produced in the national dimension. Furthermore, the spatial pattern of municipalities affected by a particular type of impact on territorial cohesion differs between the two dimensions. Almost 40 percent of Polish municipalities experienced an adverse impact on territorial cohesion, depending on whether we use the national or international perspective. These confusing results support our argument that there is a need to simultaneously use the national and the international perspective when evaluating improvement in accessibility and its impact on territorial cohesion. The less accessible areas affected by an impact that operates in an anti-cohesion manner at both national and international dimensions should be recognized as areas that have a particular need to be considered during the next stage of the big push for roads. The focus on these areas, almost neglected during the last programming period, is in line with national as well as European policy goals.

The proposed methodology may be applied to future research that should focus on the ex-post

evaluation of changes in accessibility and their territorial cohesion impact during the 2014–2020 programming period (the next "big push" decade). Moreover, the evaluation may be broadened to include railway investments and changes in multimodal accessibility. The causal relationships between territorial and socio-economic inequality, as well as the impacts of infrastructure investments on socio-economic development, are also worth investigating.

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