EVALUATION

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European Funds
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GLOSSARY OF TERMS AND ABBREVIATIONS USED IN THE REPORT

A	Motorway
AAI	Air Accessibility Indicator
CEF	Connecting Europe Facility
CF	Cohesion Fund
ERDF	European Regional Development Fund
ESPON	European Observation Network for Territorial Development and Cohesion
EU	European Union
GDDKiA	General Directorate for National Roads and Motorways
GDP	Gross Domestic Product
GIS	Geographical Information System
GUS	Central Statistical Office
IGSO PAS	Institute of Geography and Spatial Organization PAS
ISPA	Instrument for Structural Policies for Pre-Accession
KPZK	National Spatial Development Concept 2030
MAI	Multimodal Accessibility Indicator
OGAM	Open Graph Accessibility Model
OP DEP	Operational Programme Development of Eastern Poland
OP EP	Operational Programme Eastern Poland
OP IE	Operational Programme Infrastructure and Environment
PAD	Potential Accessibility Dispersion Indicator
PKP PLK	PKP Polish Railway Lines
RaAI	Railway Accessibility Indicator
RoAI	Road Accessibility Indicator
RoAIa	Road Accessibility Indicator with destinations outside Poland
ROP	Regional Operational Programmes
S	Expressway
WIAI	Water Inland Accessibility Indicator

1. Introduction. Development of transport infrastructure in Poland

Compared to other Central and Eastern European countries, Poland suffered an exceptionally long break in implementing large transport investments. Starting around 1980, it continued *de facto* until the time of the country's accession to the European Union. During those 25 years, few new routes were created. No new vision of the road and railway system development was elaborated either. Instead, plans of the target network layout created during the planned economy times were copied (also in European documents). In these conditions, emergence of the European Union support for major new undertakings (starting with the pre-accession ISPA programme) resulted in fast, though sometimes chaotic, intensification of investment activities. In the pre-accession period and during the first financial EU perspective (2004-2006), the country managed to implement just part of the initials plans. At the onset of the second post-accession financial perspective (2007-2013), the authorities started paying attention to the need for clear specification of the goals of the individual investment projects (Komornicki 2007).

In 2007-2015, Poland started forming a network of fast traffic roads (by which we understand here both motorways and expressways), whose layout started (especially in western Poland) to gain the first features of cohesion. Less spectacular successes were achieved in developing the railway network. Until 2006, large transport investments were implemented centrally under the Operational Programme Transport. In the 2007-2013 perspective, the greatest actions were taken under the Operational Programme Infrastructure and Environment. At the same time, other transport investments were implemented with help of Regional Operational Programmes (16 voivodeships) and the Operational Programme Development of Eastern Poland. Smaller tasks in the borderlands were also supported from the European Territorial Cooperation funds.

Poland was, and still is, one of the greatest beneficiaries of structural aid, both in general and in transport. Just in the 2007-2013 perspective, the total value of transport projects exceeded PLN 99 M, with most of the money allocated to road investments. Under both financial perspectives, European Union funds were used to build a few sections of a latitudinal trunk road joining the German and Ukrainian borders through Wrocław and Kraków (A4 motorway). The central fragment of the Berlin-Warsaw motorway (A2 motorway) was also built, as well as a few fragments of the Gdańsk-Katowice-Czech border (Vienna) route (A1 motorway). In addition, a few express road lines were built (among others, Łódź-Wrocław).

In the railway infrastructure, the largest investment projects lasted very long, and were continued through consecutive financial perspectives. Such projects included modernizations of the Warsaw-Gdańsk and Warsaw-Łódź lines, of the latitudinal line from the German border via

Wrocław and Kraków to Rzeszów, as well as, among others, of the line from the capital towards the Belorussian border. A specific feature of European Union funds utilization in the transport sector in Poland was a considerable share of agglomeration projects (among others, the underground in Warsaw, new tram lines, intra-urban road routes), port projects (facilities in Gdańsk, Gdynia, Szczecin and Świnoujście), expansion of almost all airports operating in the country, as well as construction and launch of three new airports for regular flights (in Modlin, Lublin and Szymany).

Infrastructural investments were (especially during the first financial perspective) rather dispersed. Despite the initial modal balance, in the end decisively larger funds were used in road transport. Due to the very bad initial condition and enormous investment needs, neither the road nor the railway system were closed at the end of the perspective (2007-2013). As a result, the objectives were not achieved to the extent achieved e.g. in Hungary, the Czech Republic and Slovenia (Komornicki 2013). This necessitated continuation of broadly planned actions during the present financial perspective (2014-2020). Compared to the preceding ones, it is (in line with European Commission's recommendations) oriented more at railway infrastructure. Investments in air transport are totally ruled out (except those connected with security improvement). A specific framework has also been imposed on the individual operational programmes. New financial instruments have emerged (among others, CEF). At present, part of the subsequent investments are already underway. Poland is at the infrastructure development stage which already allows for a comprehensive ex post evaluation of the completed tasks, and at the same time generates the need for a precise indication of new priorities (ex ante evaluation).

At the same time, Poland saw substantial changes in the provisions of strategic plans with regional and spatial dimensions (KSRR, KPZK 2030), and hence in the method and scope of transport investment evaluation. The condition of infrastructure started to be perceived as a barrier to regional development, and accessibility improvement became one of the strategic objectives of the National Spatial Development Conception. This was connected with change in the spatial development paradigm and raising of the rank of internal connections between the main development poles (so-called network metropolis; Korcelli et al., 2010). An important factor was also absorption of substantial European Union funds. It enforced convergence of regional and transport policy objectives. Transport investments in Poland became an element of the cohesion policy, and one of the main assumptions of that policy in the period after 2014 became greater orientation at measurable effects of the intervention undertaken. This necessitated divergence from purely technical criteria of project evaluation. Increased importance was gained by economic evaluation and territorial effects, and in consequence comprehensive and modern result indicators. Another necessity was also separate evaluation of the same investments in various geographical scales. This gave rise to demand for modern evaluation indicators that would allow for evaluating achievement of spatial objectives using tools in the form of construction and modernization of transport networks.

At the same time, more and more documents (among others, Agenda Terytorialna Unii Europejskiej 2020) perceive infrastructure development in terms of improvement in spatial accessibility (in various geographic scales), while pointing out the need to territorialize the effects of the transport policy employed. In turn, the balancing of transport emphasized in all documents (Objective

7 of the EU regulation concerning ERDF and CF) requires development of a methodology allowing for an efficient identification of effects from the modal viewpoint. Indicators meeting the requirements outlined above turned out to be transport accessibility measures, including first of all potential accessibility measures.

Correct **evaluation of transport investments** financed under different operational programmes (two national ones: Operational Programme Infrastructure and Environment and Operational Programme Development of Eastern Poland/Eastern Poland, and 16 Regional Operational Programmes) requires comprehensive analysis of the influence of those investments on transport accessibility changes (Komornicki et al. 2013). Accessibility changes concern multiple transport modes simultaneously (among others, road, railway, air and inland water transports). From this viewpoint, the factor of key importance is using a **synthetic accessibility indicator in a multimodal approach** (Komornicki et al. 2008).

Since during the last two decades a large part of investments were realized with participation of European Union funds, the time range of evaluation analyses is determined by the programming periods. In Polish conditions these are first of all the 2007-2013 period (with the possibility of settling the projects until 2015) and the presently running period of 2014-2020 (2023). In the former case, *ex post* evaluation of transport investments is possible, and in the latter – mainly the *ex ante* one. *Ex ante* evaluation is conditional on possessing possibly confirmed information on the planned actions (together with their scale, exact location and completion time). Investment plans undergo changes, adapting themselves to political cycles and financial capacity of the state. Nevertheless, due to the long and complicated process of preparing the individual projects, corrections radically changing the target layouts of transport networks are rare. This is why *ex ante* evaluation is valuable as a significant point of reference even if the whole investment process is slowed down.

This publication results from research conducted under the project titled „*Oszacowanie oczekiwanych rezultatów interwencji za pomocą miar dostępności transportowej dostosowanych do potrzeb dokumentów strategicznych i operacyjnych dot. perspektywy finansowej 2014-2020*" [Estimation of expected intervention results using transport accessibility measures adjusted to the needs of strategic and operational documents concerning the financial perspective 2014-2020] by the Institute of Geography and Spatial Organization of the Polish Academy of Sciences on the order of Ministry of Infrastructure and Development in 2014-2015. The following detailed research objectives were specified in the project:

- **OBJECTIVE I**. Adjustment of the measurement methodology for country and region transport accessibility changes under MAI to the logic and scope of intervention under the cohesion policy in the financial perspective 2014-2020;

- **OBJECTIVE II**. Estimation of the value of MAI (as modified under detailed research objective I) for the needs of program documents on the cohesion policy for the financial perspective 2014-2020 and strategic documents whose progress is monitored within the STRATEG database;

- **OBJECTIVE III**. Estimation of the temporal accessibility indicator value for the needs of strategic documents whose progress is monitored within the STRATEG database and interpretation of the results;

- **OBJECTIVE IV**. Estimation and assessment of changes in the value of MAI (as modified under detailed research objective I) for the needs of ex post evaluation of NSRF for 2007-2013;

- **OBJECTIVE V**. Development of an instruction for monitoring accessibility changes for the needs of evaluation and reporting on implementation of program documents on the cohesion policy for financial perspective 2014-2020 and of strategic documents (national and regional).

In the project, **MAI (Multimodal Accessibility Indicator)** was used for implementation of all detailed objectives. This publication is a synthesis of all reports. After a short introduction aimed at familiarizing the reader with evolution of research on MAI and adjustment of that indicator to the requirements connected with monitoring the effects of EU funds (Chapter 2), we present methodological assumptions of the analysis (Chapter 3) and, subsequently, in Chapter 4, the research results by sectors. For each transport mode, the diagnosis is presented, i.e. the accessibility status on the commune level at the beginning of 2007 and in 2023 (as the target availability level after the programming period 2014-2020, according to knowledge of investments as of mid-2014), and accessibility changes during the period (2007-2013). Changes in the 2014-2020 period are not presented in detail since investment plans undergo significant corrections. However, the scale of planned actions is large enough to justify presentation of the accessibility layout for the end of the consecutive financial perspective (even if in reality that layout will be achieved later than in 2023). For the road and railway transport, we also take into account the net effect of accessibility changes resulting from implementation of investments co-financed out of EU funds in the programming period 2007-2013, both the total investments and investments by the individual Operational Programmes (OP IE, OP EP and ROPs). The results for road transport obtained using RoAI (Road Accessibility Indicator) have been supplemented with:

- Isochronic analysis of changes in the so-called cumulative accessibility,

- Study taking into account destinations located outside the borders of Poland.

The subsequent sections present results of analyses for other transport modes, i.e. for RaAI (Railway Accessibility Indicator), AAI (Air Accessibility Indicator) and WIAI (Water Inland Accessibility Indicator), as well as synthetic results in the form of the multimodal MAI indicator. Chapter 5 is devoted to presenting the application potential of MAI in the form of its monitoring in the 2004-2023 perspective, taking into account the dispersion index (regional accessibility differentiation). The synthesis ends with conclusions and recommendations following from the research (Chapter 6), strategic conclusions (Chapter 7) and bibliography.

2. Evolution of work on the MAI indicator and its adjustment to the requirements connected with monitoring the effects of EU funds

The work on the consecutive versions on the **multimodal accessibility indicator MAI** is the resultant of long-term research on broadly understood transport geography (including spatial accessibility) and the demand for modern evaluation tools which emerged together with intensification of investment processes in the Polish transport. The existing body of earlier research allowed for fast development of the methodology. Among the foundations that allowed this we should mention earlier work carried out at the Institute of Geography and Spatial Organization PAS (among others, Potrykowski 1980, Taylor 1999, Lijewski 1986) and at Adam Mickiewicz University in Poznań (Chojnicki 1966, Czyż 2002, Ratajczak 1999). In the period immediately preceding development of the MAI methodology, we should emphasize the importance of temporal accessibility analyses conducted for the needs of the National Spatial Development Conception 2030 (Komornicki et al. 2008) and of a study on the general impact of transport investments on development (Rosik and Szuster 2008). In parallel, in Poland outside the Warsaw centre, the issue of accessibility, including potential accessibility, was, and still is, studied by, among others, Guzik (2003), Gadziński (2013), Wiśniewski (2014).

The MAI indicator in its first version was developed in 2008 by a research group of Institute of Geography and Spatial Organization PAS employees for the needs of the project: „*Opracowanie metodologii liczenia wskaźnika międzygałęziowej dostępności transportowej terytorium Polski oraz jego oszacowanie*" [Development of methodology for calculating a multimodal accessibility indicator for the territory of Poland] (Komornicki et al. 2008). The indicator was the first Polish attempt to calculate accessibility changes resulting from implementation of infrastructural investments on the poviat level in the multimodal context. Its calculation was carried out using the potential accessibility method (Fig. 1). In 2010, the first update of the indicator was carried out.

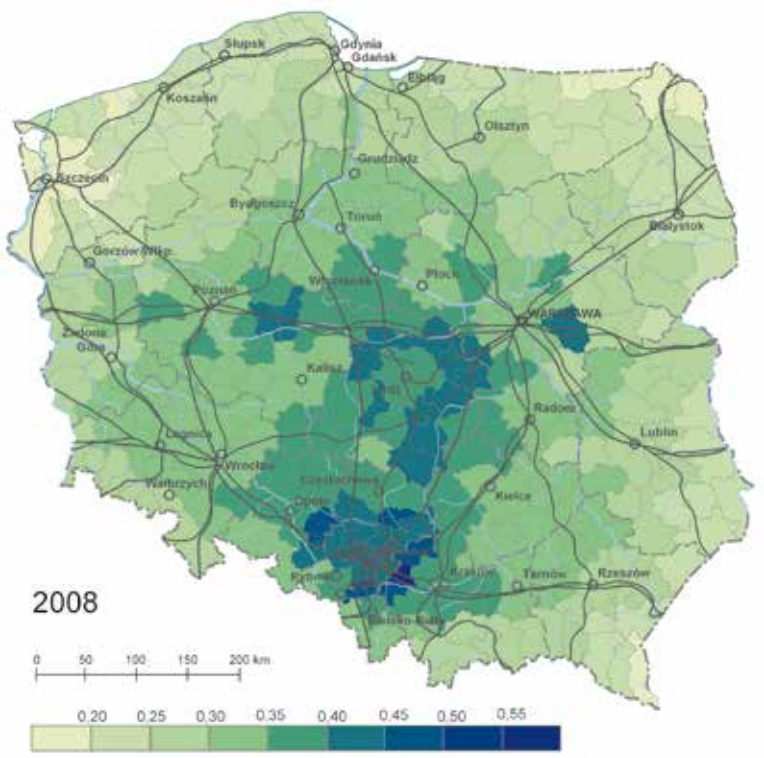

Figure 1. Multimodal Accessibility Indicator of Poland in total transport for poviat nodes and their representative poviats in 2008

Source: Komornicki et al. (2008).

Experiences in building accessibility models (including the MAI indicator) were described in the monograph: *„Dostępność przestrzenna jako przesłanka kształtowania polskiej polityki transportowej"*[Spatial accessibility as a premise for shaping Polish transport policy] (Komornicki et al. 2010a). In 2010, MAI was used for the first time in a broader evaluation context in the IGSO PAS report: *„Ocena wpływu inwestycji infrastruktury transportowej realizowanych w ramach polityki spójności na wzrost konkurencyjności regionów (w ramach ewaluacji ex post NPR 2004-2006)"* [Evaluation of the impact of transport infrastructure investments implemented under the cohesion policy on increased competitiveness of the regions (under *ex post* evaluation of NDP 2004-2006)] (Komornicki et al. 2010b). In turn, in the research project titled *„Narzędzie ewaluacyjno-badawcze dostępności transportowej gmin w podukładach wojewódzkich*" [Evaluation and research tool for transport accessibility of communes in voivodeship subsystems] (Rosik et al. 2011) implemented under Competition IV for Ministry of Regional Development subsidies, the IGSO PAS team undertook to expand the capabilities of a computer application used for accessibility studies. In its new version, the application, known as **OGAM** (*Open Graph Accessibility Model*), is an open tool based on graph theory, which allows for computing potential accessibility indicators for an arbitrary network prepared earlier in the GIS program. The road network was also expanded with sections of poviat and commune roads in order to enable connecting all cities and villages being commune seats to the accessibility model as nodes, and to enable presentation of the model results on the lower aggregation level, i.e. on the commune level (Fig. 2). The OGAM application enabled an arbitrary change in the traffic speed model parameters, which allowed for developing an original

traffic model for HGVs. The options of including (or not) the so-called own potential and applying arbitrary forms of the so-called distance decay function were also introduced.

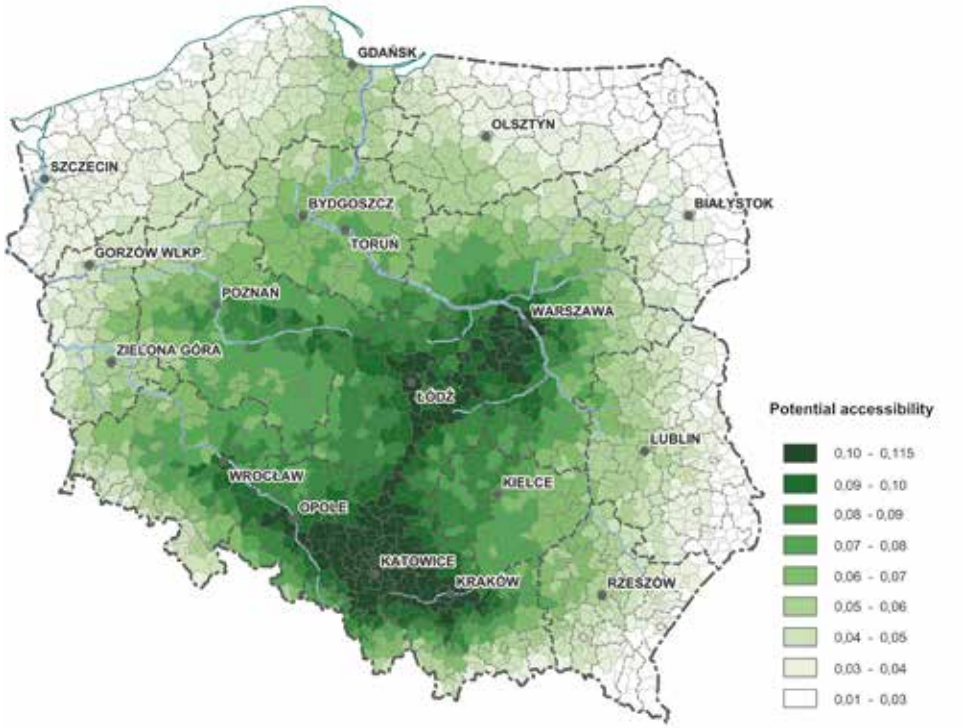

Figure 2. Road Accessibility Indicator in 2011. National accessibility of population for short journeys

Source: Rosik et al. (2011).

The first attempt at **monitoring accessibility changes on the commune level** in the national and international approach resulting from implementation of investments on **motorway and expressway networks** in Poland in the long term perspective, i.e. in 1995-2030, took place under the project *Monitoring spójności terytorialnej gmin w skali krajowej i międzynarodowej w latach 1995-2030*" [Monitoring of territorial cohesion of communes in the national and international scales in 1995-2030] (Rosik et al. 2012a) implemented under Competition V for Ministry of Regional Development subsidies. In the international context, we have used research the methodology of accessibility analysis developed within the monograph: *„Dostępność lądowa przestrzeni Polski w wymiarze europejskim*" [Land accessibility of Polish space in the European dimension] (Rosik, 2012). Evaluation of infrastructural investments (motorways and expressways) with the use of EU funds with help of the MAI indicator limited to road transport (individual motoring) was one of the research subjects in the evaluation study: *„Wpływ budowy autostrad i dróg ekspresowych na rozwój społeczno-gospodarczy i terytorialny Polski"* [Impact of the construction of motorways and expressways on the socioeconomic and territorial development of Poland (Komornicki et al. 2013). In turn, evaluation of the impact of investments on the networks of voivodeship roads in the programming period 2007-2013 was the objective of the research project: *„Ocena wpływu projektów drogowych realizowanych w ramach Regionalnych Programów Operacyjnych na zwiększenie dostępności transportowej województw"* [Evaluation of the impact of road projects implemented

under Regional Operational Programmes on increasing the transport accessibility of voivodeships] (Rosik et al. 2012b). The experiences described above allowed for improving the MAI indicator's methodology and its adjustment to the requirements connected with full and continuous monitoring of accessibility changes resulting from implementation of investments co-financed out of EU funds under the project „*Oszacowanie oczekiwanych rezultatów interwencji za pomocą miar dostępności transportowej dostosowanych do potrzeb dokumentów strategicznych i operacyjnych dot. perspektywy finansowej 2014-2020*" **[Estimation of expected intervention results using transport accessibility measures adjusted to the needs of strategic and operational documents for financial perspective 2014-2020]**.

All the described development stages of the methodology for calculating the potential accessibility indicator in Poland referred to the principles described in the subject literature, and applied in parallel on the Europan level. Analogous work for the European Union territory (later for the so-called ESPON space) was carried out, among others, under the IASON, ESPON 1.2.1., ESPON 1.3.1, ESPON TRACC and ESPON SeGI projects. They were implemented by international research consortia, whose members in several cases included IGSO PAS and members of the group elaborating the methodology for calculating the MAI indicator. This ensured compatibility of the results with the results of international research.

3. Methodological assumptions of the MAI indicator

Accessibility examination methods used in the study. The starting point for deliberations on the methodological assumptions of MAI should be a brief review of methods for examining accessibility (Komornicki et al. 2010, Rosik 2012). As of today, there is no, and probably will never be, a single **definition of accessibility** universal and obligatory for all researchers. Gould (1969) points out that accessibility is one of those commonly employed terms that everybody uses but nobody can ultimately define or measure. The multidimensional character of accessibility implies the possibility of studying this phenomenon using many differentiated methods (Rosik, 2012). However, in most studies on that problem area a certain consensus prevails that allows for singling out a few most important types of methods (Geurs and Ritsema van Eck 2001, Spiekermann et al. 2013). They include:

- **infrastructure-based accessibility measure** – accessibility estimated using the indicators of infrastructural equipment of a given area, e.g. quantity and quality of linear and spot facilities of transport infrastructure;

- **distance-based accessibility measure** – here distance is understood as Euclidean distance, actual physical distance (e.g. road distance), time distance (travel time) or economic distance (travel cost) between the origin and destination of the journey or a collection of destinations;

- **cumulative accessibility** – known also as **isochronic accessibility** , and in the context of travel time utilization also as **temporal accessibility** (Komornicki et al. 2010a); accessibility is measured by estimating the set of destinations accessible e.g. within a specified travel time, at a specified travel cost or effort; e.g. number of inhabitants accessible within 15 minutes, number of hospitals accessible within 1 hour, number of student positions at university courses offered at the cost of railway ticket up to PLN 30 one way, etc.;

- **potential accessibility** – accessibility measured based on the assumption that destination attractiveness decreases with increasing distance, travel time or cost, since the traffic participant is more willing to travel shorter than longer distances; the character of destination attractiveness decrease along with the lengthening distance is shown by the so-called distance decay function;

- **person-based accessibility** – taking into consideration the individual preferences of traffic participants; a method with limited application when developing generalized conclusions regarding spatial differentiations.

The project „*Oszacowanie oczekiwanych rezultatów interwencji za pomocą miar dostępności transportowej dostosowanych do potrzeb dokumentów strategicznych i operacyjnych dot. perspektywy finansowej 2014-2020*" **[Estimation of expected intervention results using transport accessibility measures adjusted to the needs of strategic and operational documents for financial perspective 2014-2020]** used two of the above-mentioned methods, i.e. first of all **potential accessibility** (potential model), based on which the Multimodal Accessibility Indicator **MAI** was built, and temporal accessibility (isochronic analysis).

Potential accessibility is the most frequently encountered approach in studying transport accessibility (Rosik, 2012), especially in case of evaluating changes following from the development of transport infrastructure resulting from the implementation of individual projects or investment programs (Komornicki et al. 2010b, Komornicki et al. 2013, Rosik et al. 2012a, 2012b, Rosik et al. 2015). The group of models termed „potential accessibility" includes variants of accessibility measured with **potential indicators**. The most important distinction of potential accessibility is that the destination attractiveness increases together with its size and decreases along with increasing Euclidean, time or economic distance.

$$A_i = \sum_j f_1\left(M_j\right) f_2\left(c_{ij}\right) \tag{1}$$

where:
A_i – transport accessibility of commune, poviat, voivodeship *i*,
M_j – masses, e.g. population or GDP accessible in commune, poviat, voivodeship *j*,
c_{ij} – total Euclidean, time or economic (cost) distance connected with travel /transport from transport zone *i* to transport zone *j*[1].

Destination attractiveness. In constructing the MAI indicator, the needs of continuous monitoring enforced the decision to use solely the variables that are available on a regular basis in the resources of public statistics. In order to simplify the procedure, the number of variables was limited to two, i.e. **population** and **GDP**, as the variables determining the mass (travel/transport destination). For **passenger transport,** calculation of **population accessibility** indicators was adopted. In passenger transport, where the size of population fully determines the value of mass, changes in the examined period for the whole country are not spectacular, and follow mainly from population updates based on General Censuses. The changes were revealed to a greater extent in the neighbourhood of large metropolises, where in suburbanization zones population concentration occurred in the examined period. For **freight transport**, in order to take into consideration the economic (market) element, population accessibility was also used, but with addition supplementation of the **GDP** data on the sub-regional level (the data estimates were converted

[1] In study making use of MAI, the measure of distance decay is the travel/carriage time; the analysis made use of the exponential function $f(c_{ij}) = \exp(-\beta t_{ij})$, where the appropriate parameter was indicated as $\beta = 0{,}023105$ (see Spiekermann et al. 2013, Stępniak and Rosik 2013), which means that destination attractiveness decreases by half for travel time amounting to exactly 30 minutes, while for about 100 minutes the attractiveness reduces to ca. 10% (e.g. for passenger transport, when the destination is a city with 100 thou. inhabitants located within 30 minute travel time, its attractiveness decreases to 50 thou. inhabitants, while for 100 minute travel – to just 10 thou. inhabitants); in case of an international indicator, the parameter $\beta = 0{,}005775$ was used in the road transport due to the fact that foreign trips have the character of long-distance travel.

to commune and poviat levels based on the population changes in sub-regions). The assumption was that in 2004 the market element (GDP) determined the attractiveness of all destinations in Poland in 25% (which is comparable to the share of industry in GDP in Poland, and we can assume that the factor od decisive importance for freight transport is, besides the population distribution, the distribution of production plants). Then, in the following years, the economic element role increases together with increasing GDP and simultaneous stabilization of the population (taking into consideration the forecasts). Thus the total mass in freight transport for Poland is a little over 24% higher in 2023 than in 2004, with the share of market element (GDP) reaching ca. 40%, and the population element just a little over 60% mass in freight transport.

Speeds in road and railway transport. The calculation of **MAI** used the **speed model** developed at IGSO PAS, which indirectly takes into account both regulations (speed limits, lower speed in a developed area) and travel conditions (population living in the 5 km buffer from the road section and landform features). The speed model in individual traffic is to a large extent (with small modifications) based on the speed model for a dozen or so road categories used in updating the **MAI** indicator of 2010, while for **HGV transport** (trucks with trailers) it results mainly from later works (Rosik 2012). Both speed models for Poland were developed assuming the impact of the selected variables on vehicle speed[2]. The considerable level of detail in transport network databases and the „linking" of all commune locations to the network of national and voivodeship roads by adding to that network the most important sections of commune and poviat roads enabled calculation of the MAI indicator on the commune level. Similarly, in railway transport the railway line network prepared is much more detailed. The **speed model for railway transport** was made realistic according to the maximum technical speeds for passenger and freight trains in the network managed by PKP PLK in 2004-2014 (data acquired by courtesy of PKP PLK S.A.). Speed changes in the railway network were assumed to follow from either network degradation (speed reduction) or infrastructural investments (speed increase). In case of investments undertaken in 2015-2020, additional information was obtained on changes in maximum technical speeds on a given section after its commissioning. In this way, precise knowledge was obtained regarding changes in maximum technical speeds for 2004-2014 and speed changes forecasted for 2015-2023. Accessibility changes forecasts for 2014-2023 for both road and railway transport were made based on the assumption that the only factor influencing speed changes would be infrastructural investments implemented w Poland. The measures aimed at determining more realistic speeds in road and railway transport, divided in passenger and freight transport, allowed for more precise evaluation of the impact of specific investments within the individual modes, especially on accessibility improvement in freight transport (in reference to the objectives of balanced transport development).

Infrastructural investments in road and railway transport. During the research work, we obtained support from a series of beneficiaries regarding the lists of investments in road and railway transport. In the **road sector,** analysis of investments on the national and voivodeship road

[2] This form of speed model with minor changes was prepared based on the databases available at IGSP PAS under projects implemented by IGSP PAS, among others, Komornicki et al. (2008), Rosik and Śleszyński (2009), Rosik et al. (2011) and Rosik (2012).

network (and in exceptional cases on key poviat roads) was assumed. When completing the lists of investments (status as at July 2014), we cooperated with:

- General Director for National Roads and Motorways (GDDKiA) – information on investments on national roads (Dokument Implementacyjny[3]),
- 16 Marshal's Offices – information on investments on voivodeship roads identified in the process of negotiating territorial contracts,
- 66 City Offices of cities with poviat rights – information on investments in cities with poviat rights.

Each of beneficiaries was asked to provide the relevant data characterizing the investment. GDDKiA sent files with the exact courses of all planned investments, including location of the nodes. In addition, lists of investments on national roads were supplemented for motorway sections built by private concessionaries.

Elaboration of results for the **railway sector** was carried out in cooperation with PKP Polskie Linie Kolejowe S.A., which resulted in obtaining information on all the greatest investments implemented on the network managed by PKP PLK S.A., together with information on changes in maximum technical speeds resulting from the implemented investments (the list compiled, among others, on the basis of Dokument Implementacyjny[4]). In addition information on planned investments on railway lines identified during the negotiations of territorial contracts was obtained from **16 Marshal's Offices**. For **other transport modes**, (air and water inland transport), the list of investments was prepared based on generally available information on the implemented and planned infrastructural investments at airports and on the waterway network for inland navigation.

The calculation of MAI took into account all investments in road and railway transport meeting at least one of the following **conditions**:

- Joint amount of the project exceeds PLN 30 M[5],

[3] The Implementation Document represented the ranking of road investments to be implemented in the financial perspective 2014-2025. In the end it did not gain validity (in autumn 2015, the authorities decided that by 2025 all expressways and motorways set forth in the Ordinance of 2004 on the target layout of those routes, as amended, would have been built). Nevertheless, the tenders announced in the new perspective (after 2014) concerned almost exclusively the routes set forth in the Implementation Document. It remained the list of best prepared investments, whose final implementation by 2023 is most probable.

[4] In case of railway investments, we decided to take as those to be implemented by 2023 all investments recorded in the Implementation Document.

[5] The limit condition of PLN 30 M was set in order to prevent taking into account a large number of investments by some beneficiaries and not taking this type of investments into account by other beneficiaries (Rosik et al. 2012b). In case of cities with poviat rights, an additional assumption adopted was that investments important from the viewpoint of accessibility changes were those that represented routes with traffic separation or consisted in increasing the number of traffic lanes. The necessary information was obtained from GDDKiA, PKP PLK and 16 Marshal's Offices. In case of cities with poviat rights, filled-in investment forms were obtained from all 18 voivodeship cities, and, including the voivodeship cities, from 47 cities with poviat rights, 6 cities declared absence of investments meeting the criteria, and 13 cities did not deliver any information on investments.

– Length of a linear project exceeds 10 km;

– The project represents a ring road or a bridge structure.

The total number of all implemented and planned investments entered in the database considerably exceeded **one thousand**. Network update in order to enter the investments into the model required the adjustment to the requirements of calculating MAI for a few thousand of network sections (each investment consisted of multiple network sections).

Air accessibility. Air accessibility was assumed to result on the one hand from the **time of travel** to all airports in the country, and on the other hand to depend on the **airport capacity**. All major investments carried out at airports and aimed at increasing the capacity of terminals were taken into consideration. Attractiveness of an airport was assumed to be analogous to its capacity.

Water inland accessibility. The investments taken into account included those significantly improving technical solutions on the Odra Waterway, lower course of Vistula and Noteć as a waterway joining Vistula to Odra (together with the Bydgoszcz Channel, Brda and Warta). River harbours were assigned (analogously as in case of airports) a specific „capacity" following from the class of waterway that was indicated as „mass" in the accessibility model. Thus accessibility change followed from improvements in the operation of waterways (increasing the class of waterways) or improvement in access to waterways with HGV transport (investments on the road network).

Modal indicators. The potential model is a basis for calculating **modal indicators** (independently for each transport mode) on the countrywide level. In **passenger transport,** the modes distinguished include road, railway and air transport (domestic routes). Based on both GUS data and the expert opinions of Prof. Burnewicz (Burnewicz 2010), the share of inland and coastal navigation, as well as marine shipping, in domestic passenger transport was recognized as a trace one (ca. 0.1% in all) and irrelevant from the viewpoint of modal as well as synthetic indicators. In **freight transport,** the modes distinguished include road (HGV), railway and water inland transport. The shares of air transport and domestic marine trading were recognized as trace ones and irrelevant for accessibility indicators in freight transport.

The synthetic indicator MAI resulted from two-stage aggregation of indicators: first to the transport type (passenger transport and freight transport) level, and then from two transport types to a single synthetic indicator. The national MAI indicator (passenger and freight types) was prepared based on the actual transport activity carried out by the individual modes on the country level. The analysis of modal division in **passenger transport** was conducted using the following variables concerning transport activity:

– Road transport: individual motoring under long distance domestic travels and extra-urban buses in domestic communication (based on the Central Statistical Office (GUS) data),

– domestic railway communication (based on GUS data),

– air transport in domestic communication (based on GUS data).

The analysis of modal division in **freight transport** was conducted using the following variables concerning transport activity:

- domestic road transport (based on GUS),
- railway transport – internal dispatches (based on GUS),
- water inland transport (based on GUS).

The synthetic indicator MAI is created based on shares of the individual modes in the modal division. For simplicity, we have assumed that there were no changes in the shares of the individual modes in the transport activity in the examined period, and that they were equivalent to the shares as of 2013 (Tab. 1).

Table 1. Shares of road, railway and air transport in passenger transport and of road, railway and water inland transport in freight transport

Passenger transport		Freight transport	
Transport mode	Transport activity share	Transport mode	Transport activity share
Road	89.2%	Road	78.0%
Railway	10.6%	Railway	22.0%
Air	0.2%	Water inland	0.04%

General definition of the MAI indicator. MAI (Multimodal Accessibility Indicator) shows the sum of transport routes between centres and regions, whereby each route takes into account both the time of travel between centres A and B and the importance (attractiveness) of those centres in the transport system. Entities with a higher value of the indicator are characterized by higher accessibility. The indicator is built based on the potential model, in which the destination attractiveness (population in passenger transport and population together with GDP in freight transport) decreases with lengthening travel time. The accessibility indicator is calculated separately for each transport mode on commune, poviat, voivodeship, macro-region and country levels. In this way, for each level of spatial analysis separately, we obtain modal indicators: road indicator (RoAI), railway indicator (RaAI), air indicator (AAI; for passenger transport only) and inland shipping indicator (WIAI; freight transport only). These indicators can be aggregated for an arbitrary spatial and administrative entity for two transport types (passenger and freight transport), and synthetic indicators can also be calculated within the spatial levels of analyses. The synthetic indicator on the transport type level is the sum of products of modal indicators and shares of the individual modes in the transport activity for a given transport type. The synthetic multimodal indicator (MAI) is the average of the synthetic indicators obtained for passenger and freight transport. Synthetic modal indicators (the road and railway indicators) are the averages of the appropriate modal indicators for passenger and freight transport. Changes in the values of all indicators are calculated based on taking into account all transport investments either actually implemented or planned for implementation.

Table 2. Potential accessibility MAI indicators for passenger and freight transport and synthetic indicators (modal and multimodal ones) calculated within the study (grey fields denote absence of indicator calculation)

Transport mode	Passenger transport	Freight transport	Modal synthetic indicator	Multimodal synthetic indicator
Road	Passenger RoAI	Freight RoAI	RoAI	
Railway	Passenger RaAI	Freight RaAI	RaAI	
Air	AAI			
Inland shipping		WIAI		
Synthetic indicator	Passenger MAI	Freight MAI		Synthetic MAI

Spatial scope. On each spatial level of the analysis below the national one, i.e. from the commune level through the voivodeship level up to the macro-region level, accessibility analysis is prepared based on all routes between an arbitrary pair of communes in Poland (matrix layout). The indicators obtained on the commune level are appropriately aggregated to the poviat, voivodeship and macro-region levels. The conducted verification enabled calculation of the MAI indicator as the net effect of implementation of various strategic documents, as well as of the individual (national and regional) Operational Programmes, macro-regional and regional strategies.

4. Examples of indicator applications (measurements)

Application possibilities of the MAI indicator are shown in the sector-based approach (road, railway, air and water inland transport), each time starting with the diagnosis of the phenomenon and changes in a general approach. In case of road and railway transport, we also show accessibility changes as a result of implementation of the individual EU funds in the programming period 2007-2013, total accessibility changes resulting from implementation of investments co-financed from EU funds during the same period, as well as the share of those changes in the general accessibility change. In road transport, the analysis is additionally conducted using the RoAIa indicator (taking into account destinations outside Poland), as well as with the use of isochronic analysis for access to voivodeship centres. The possibilities of using the MAI indicator in forecasting, i.e. for the programming period 2014-2020 according to the state of knowledge on infrastructural investments as of mid-2014, can be learnt by reading the relevant raport on the Ministry of Development website.

4.1. Road indicator RoAI

Regional differentiation in road accessibility in Poland in 2007 corresponds to the results of earlier research (among others, Komornicki et al. 2010, Rosik 2012). The spatial layout (Fig. 3) is a **two-pole one**, **with the best accessibility centres in the region of the Upper Silesia conurbation together with Cracow and Warsaw (in later years – also Łódź)**. A higher level of the indicator is also noticeable in a broad neighbourhood of the above-mentioned poles. On the voivodeship level, the decidedly highest accessibility level in 2007 was observed in the Silesian region, a and a high one also in the Lesser Poland (Małopolska), Mazovian, Łódź and Opole regions. In the cartographic layout, other large cities also distinguish themselves to a higher degree – examples include Poznań, Wrocław and Lublin, as well as Gdańsk (as a separate "island"). Freight transport (freight RoAI) is characterized by clearly greater polarization of the indicator values than in passenger transport (passenger RoAI). The Warsaw and Upper Silesia conurbation poles are much more distinguished, while the role of other centres is clearly smaller. In general, better accessibility zones are linked to a polygon, based in passenger transport on Wrocław, Poznań, Gdańsk, Warsaw, Lublin, Rzeszów, Cracow and Katowice. The polygon can be identified with the **network metropolis** postulated in the KPZK 2030 document (Korcelli et al. 2010**)**. In turn, analysis of RoAI distribution (HGV transport), which was conducted using lower vehicle speeds and taking into account the GDP level as

a component of the mass of examined entities, shows a slightly different spatial image. The accessibility range is more limited spatially, being based on Wrocław, Poznań, Bydgoszcz, Warsaw, Krakow and Katowice. The synthetic approach remains the resultant of both types of transport. In 2007, the poorest accessibility areas were concentrated in north-western and north-eastern Poland, as well as along the country borders. The poorly accessible border zones were wider at the western and eastern borders, and very narrow (or vanishing) at the southern border. The worst situation occurred in peripheral voivodeships, including especially Podlasie and Western Pomerania. The most underprivileged peripheries were zones covering: the belt of western and central coastal regions, eastern Masuria and Suwałki region, the eastern borderland belt in Lubelskie and Podlaskie Voivodeships, and the region of Bieszczady and Lower Beskidy mountains.

Already in 2015 due to infrastructural investments individual routes are revealed as generating better road accessibility, which in this context might contribute to deliberations on the complementarity of individual investments and their possible staging. Accessibility on the whole length of certain routes can be perceivably improved even by investments undertaken on certain sections only (especially in **bottlenecks** of the system, e.g. construction of ring roads). This can be a motivation for starting some road investments in the current financial perspective, even if budget capabilities do not allow for completion of the whole routes. On the other hand, staging of actions should take into account the effectiveness of already completed sections, giving priority to investments resulting in accessibility improvement with greater spatial range.

The distribution of RoAI indicators in **2023** (after implementation of all investments taken into account according to the state of knowledge as of 2014) (Fig. 4) retains the two-pole layout in case of the **passenger** indicator, though the role of other centres located on the pentagon nodes seems to be reinforced. The network metropolis is also extended, covering with its range Rzeszów and Lublin, and to a lower degree also Białystok. The spatial layout of the area with better accessibility starts looking like the triangle known from earlier planning studies, based on the southern border and having its nodes in the Three-City and in the Legnica and Przemyśl regions. The main road routes are also better visible, including new investments, such as the S8 expressway Łódź-Wrocław or the line of expressways S17/S19 from Warsaw via Lublin to Rzeszów. In case of the distribution of the **freight** RoAI indicator, the importance of individual road investments (except A1) is slightly lower. Thus the main metropolises had "come closer" to each other to a greater degree in the passenger traffic than in the freight traffic. Due to the undertaken investments, the general image (**synthetic RoAI**) resembles to a higher degree than before a spider's web, based on the most important routes. Among the detailed peripheral areas with the lowest potential accessibility, significant improvement can be noted in case of the seacoast area (effect of constructing the S6). Other areas of poorer accessibility are spatially limited (to narrow belts along the borders), but still exist. There are also still visible areas within the defined pentagon that, despite a relatively small distance to the metropolis, are still relatively poorly accessible by road. They include southern Greater Poland (Wielkopolska), the borderland of Mazovian, Kuyavian-Pomeranian and Warmian-Masurian Voivodeships, as well as the western part of the Świętokrzyskie Voivodeship.

In case of relative (percentage) changes in 2007-2015 (programming period 2007-2013 + 2 years when investments co-financed during this period were being completed), the effect is spatially widespread, but relative increments are concentrated in the direct neighbourhood of

the interchanges on new motorways and expressways (Fig. 5). The widespread impact found, among others, in eastern Poland, is in part an effect of investments implemented outside that macro-region, and in part the result of a low basis (very poor accessibility in 2007). Local effects exceeding 40% were noted in the neighbourhood of interchanges on the central (Warsaw – Łódź) and western (near the German border) section of A2, northern section of A1, eastern section of A4 and northern section of S3 (from the A2 motorway to Szczecin). At the same time, an effect of a similar scale was obtained locally, in the places when a new investment served entities adjacent to the country border. This was the situation at the Czech border, in the region of the border section of A1, on the Slovakian border in the Żywiec region (expressway S69) and at the border with the Kaliningrad district of the Russian Federation (the result of completing expressway S22). The areas that gained least from the road investments in 2007-2015 were: Central Pomerania, Lithuanian borderland, eastern Lublin region and the central part of the Opole Voivodeship. The reach of net positive effects in freight transport is greater, and covers e.g. the whole Mazowian Voivodeship. This is caused by concentration of GDP increase in the largest metropolises. As a result, the areas located in their neighbourhood (especially in the neighbourhood of Warsaw and the Upper Silesia conurbation) improve their accessibility also regardless of undertaking any new investments.

A separate problem (especially in passenger transport, but also in the synthetic image) is the mentioned **location of interchanges** on motorways and expressways. It determines the access to those routes from lower rank roads, and so is the factor determining the spatial reach of the net positive effect. Strong accessibility differentiation among the entities near the interchanges and in their direct neighbourhood can be observed, among others, along the central section of A1, as well as on the western concession section of A2. These results are in line with those obtained earlier during evaluation of the effects of motorway and expressway construction (Komornicki et al. 2013), and hence are a premise for conducting variant-based *ex ante* analyses of accessibility already at the initial stage of preparing new investments.

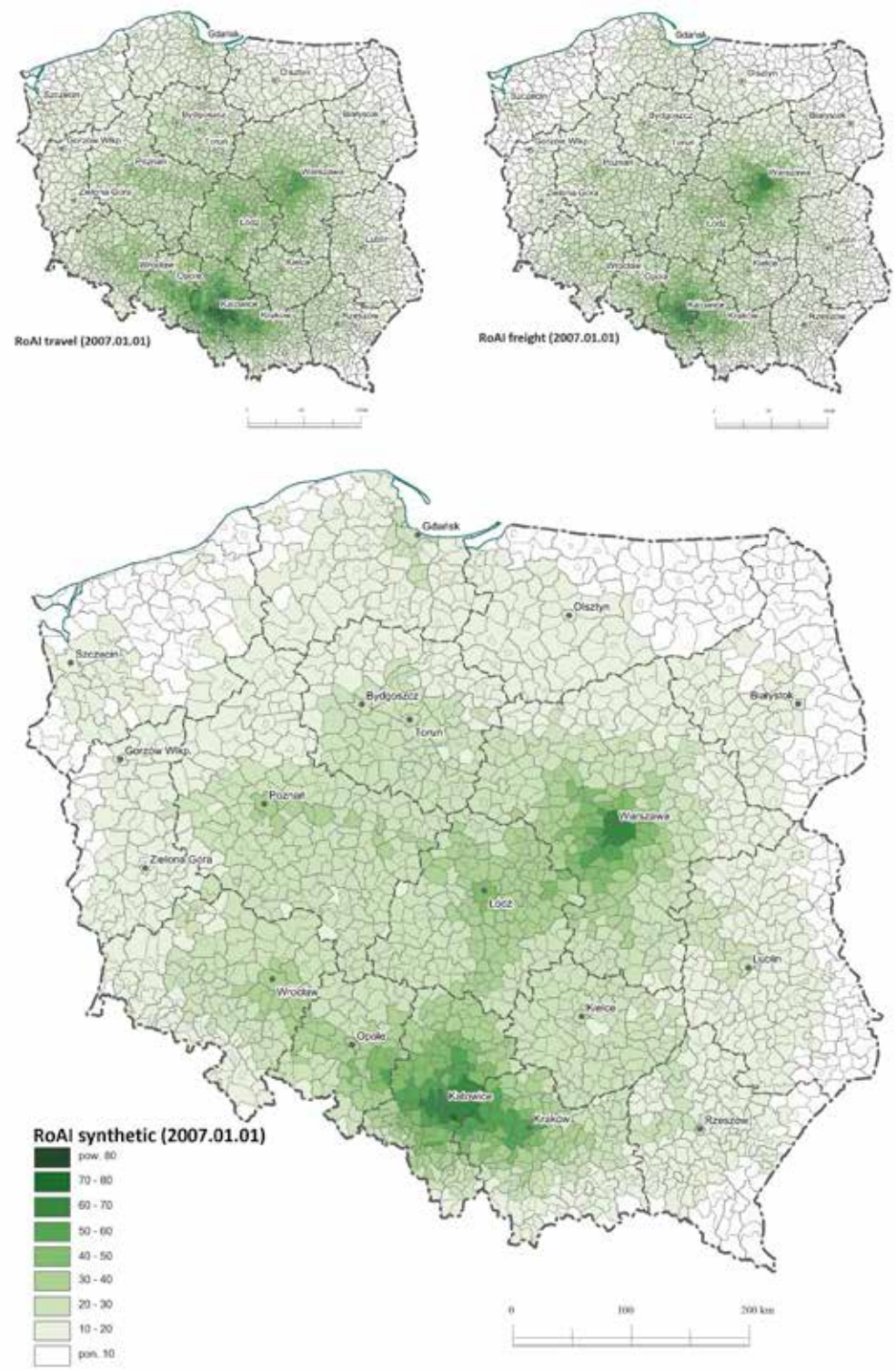

Figure 3. Road Accessibility Indicator RoAI (travel, freight and synthetic) – value as at 2007.01.01

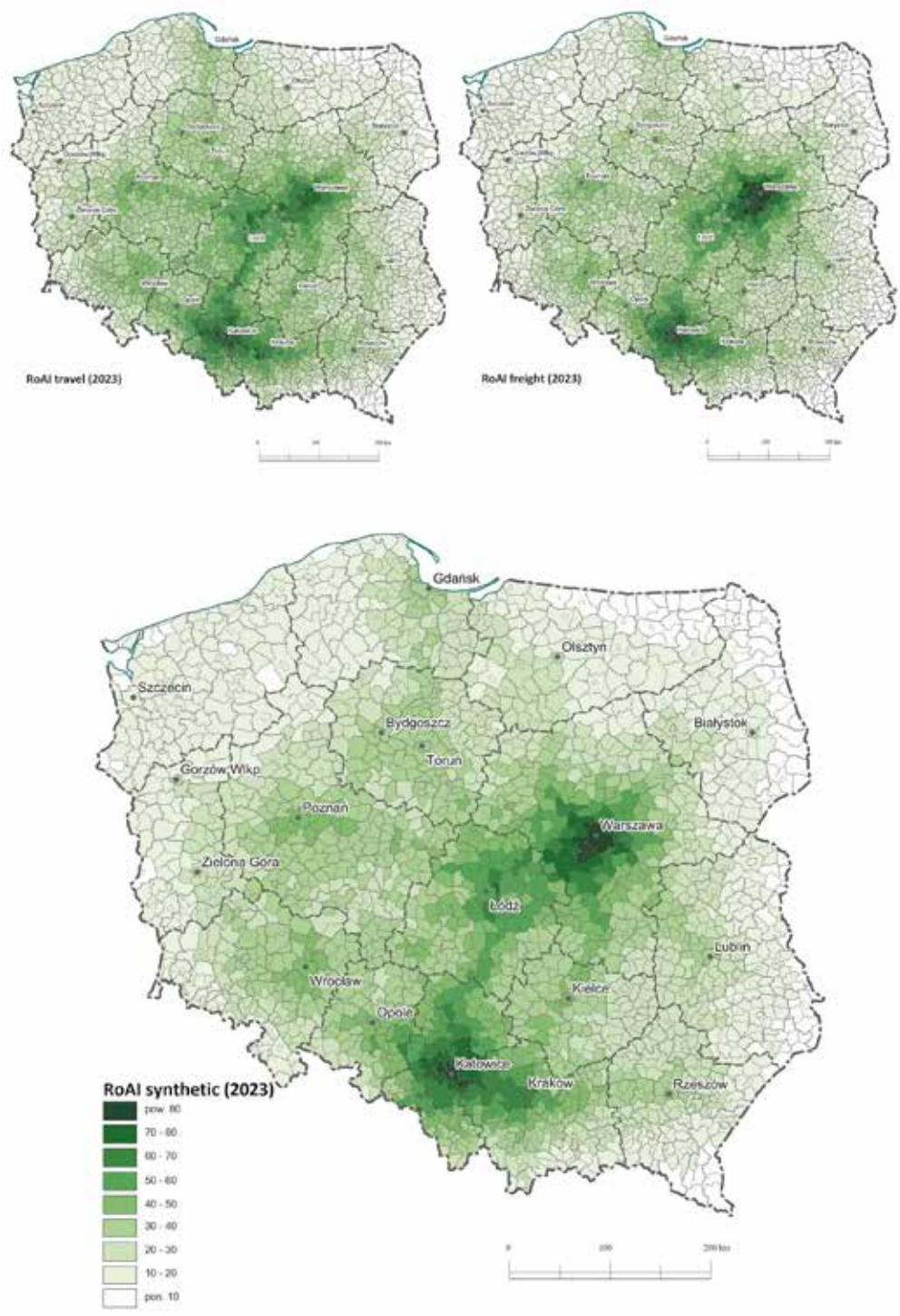

Figure 4. Road Accessibility Indicator RoAI (travel, freight and synthetic) – value in 2023 (assuming implementation of investments according to the state of knowledge as of 2014).

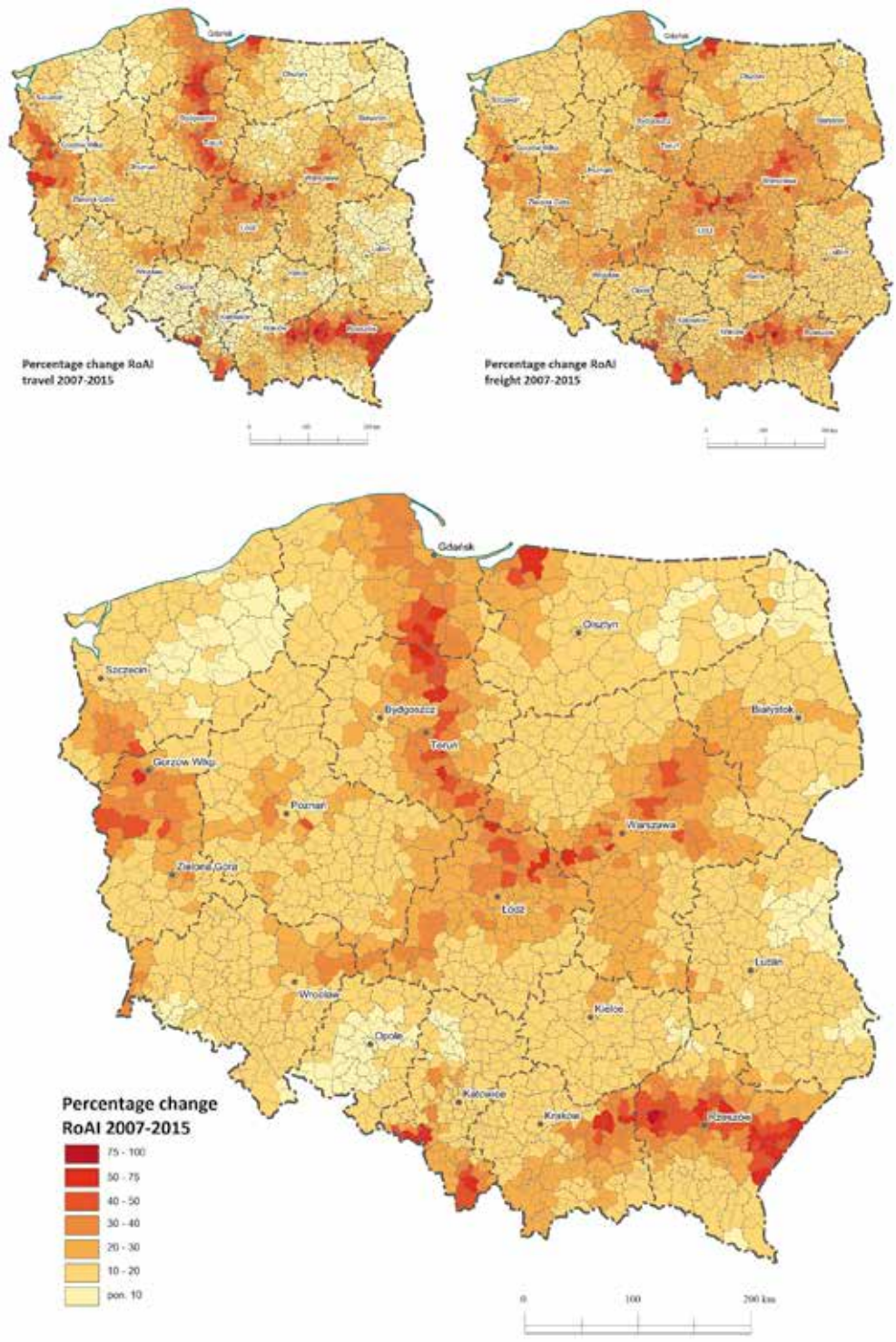

Figure 5. Percentage change in the Road Accessibility Indicator RoAI (travel, freight and synthetic) in 2007-2015

One of the basic evaluation tasks is to compute the net effects of accessibility changes resulting from the implementation of investments co-financed under the individual operational programmes, i.e. OP IE, OP EP and ROPs. Each time, the net effect was examined by comparing the situation at the end of the programming period with and without the investments implemented under the given fund.

Road investments under the **Operational Programme Infrastructure and Environment** during **2007-2015** brought the greatest net effect in the Subcarpathian, Łódzkie and Lubuskie voivodeships. The effects concentrated in the Łódzkie Voivodeship (thanks to the investments on A1 and on S8), in the belt running from the Ukrainian border through Rzeszów to Tarnów and Cracow (A4), and in the belt from Zielona Góra to Szczecin (S3). Exclusion of the northern section of A1 (built in the concession system) resulted in a moderate size of the benefits noted in the Three-City. At the same, the effect of the fragments of expressway S7 built in the Warmian-Masurian Voivodeship is more marked. Also some other smaller investments show their importance, like the western (S11) and eastern (S5) ring roads of Poznań, the ring road of Mińsk Mazowiecki (A2), and a section of S12/S17 in the Lublin region. The latter investment also yields a clear effect in the entire southern Lublin region. At the same time, it does not result in accessibility improvement in the zone between Lublin and Warsaw. This situation is different from that noted along the S8 line, where even a short intra-agglomeration section in Warsaw results in accessibility improvement for the whole zone between the capital and Białystok. **Commencing the investment from the largest nodes, concentrating demographic and economic potential, results in an immediate effect in the whole area served by the road** (the example of S8 in the Białystok direction). Commencement of the investment from the side of a smaller regional centre (the example of S17) results in a mainly local importance of the action, while the spatial range of the accessibility improvement effect is smaller and moved away to even more peripheral zones (Fig. 6).

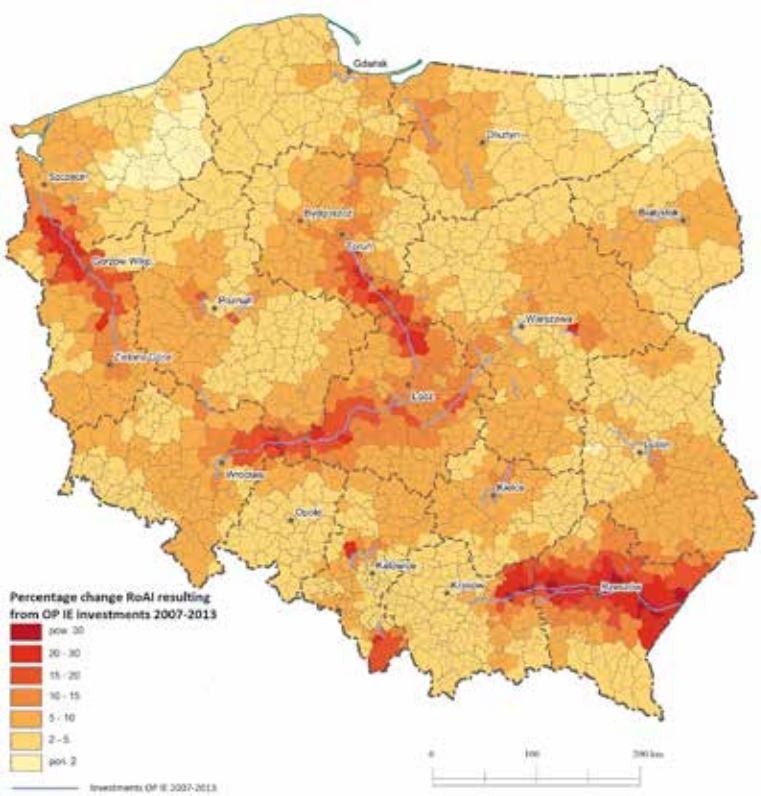

Figure 6. Percentage change in the synthetic Road Accessibility Indicator RoAI resulting from investments co-financed from OP IE in the programming period 2007-2013

In case of the **Operational Programme Development of Eastern Poland** in 2007-2015, the decidedly greatest impact of road investments can be observed in the Świętokrzyskie Voivodeship, and next in the Lubelskie and Subcarpathian Voivodeships. The principles of undertaking transport investments in OP DEP determined a limited spatial range of the effects of those actions. The decidedly most effective investments turned out be the two connected with new bridges over the Vistula river. This concerns first and foremost the bridge in Kamień, on the line of voivodeship roads joining southern Mazovia and the northern part of the Świętokrzyskie Voivodeship with Lublin. The bridge was built on the longest section of the river that until that time had no permanent crossing. The effect of the second bridge in Połaniec (on the route from Kielce to Mielec) was intensified by the investments on the lines of voivodeship roads in the Świętokrzyskie Voivodeship. The impact ranges of both investments cover a rather widespread area in four voivodeships. Benefits appear sometimes in areas rather distant from the bridges. Other investments co-financed from OP DEP whose local importance proved significant were the routes built in the neighbourhood of the country borders, improving access to the national road network from extremely peripheral areas. These were first of all a fragment of the Białystok ring road (strong effect in the Belorussian borderland) and the ring road of Olecko (improvement in the accessibility of the eastern part of the Warmian-Masurian voivodeship, at the border with Russia) (Fig. 7).

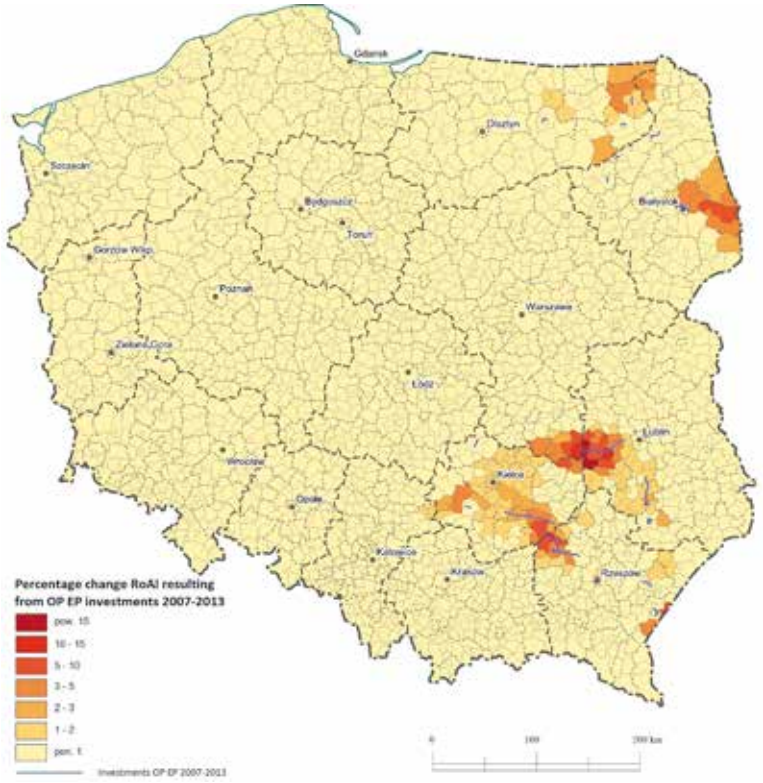

Figure 7. Percentage change in the synthetic Road Accessibility Indicator RoAI as a result of investments co-financed from OP EP during the programming period 2007-2013

In case of the **Regional Operational Programmes** implemented in 2007-2015, we can conclude that only some of the investments caused accessibility change visible in the cartographic view. This follows from the different roles of the individual voivodeship roads in the national road system. Many of them do not take over long-distance traffic (even from neighbouring areas). Thus their modernization does not have a large impact on the countrywide accessibility and brings only local changes. Also the character of modernization investments itself implies that speed increase is often rather small. All in all, the **effect of investments from ROPs** is more visible in the peripheral areas of the country. It is where the effect of a „low basis" works, and voivodeship roads more often play the role of a link to large Polish cities. Such a situation can be observed along the borders (especially along the border with the Czech Republic, Slovakia and Lithuania, and with the Kaliningrad district of the Russian Federation. The effects noted in the neighbourhood of the southern border are stronger, among others, due to its linking to the completed A4 motorway via voivodeship roads. Nevertheless, certain effects are also visible in some areas inside the country. This applies first of all to the areas when a number of routes forming the local network have been modernized in a comprehensive way, including, among others, the areas: on the border of the Warmian-Masurian and the Kuyavian-Pomeranian Voivodeships, in the Świętokrzyskie Voivodeship and on its border with the Lesser Poland Voivodeship, as well as in the longitudinal road lines in the Greater Poland Voivodeship (Fig. 8).

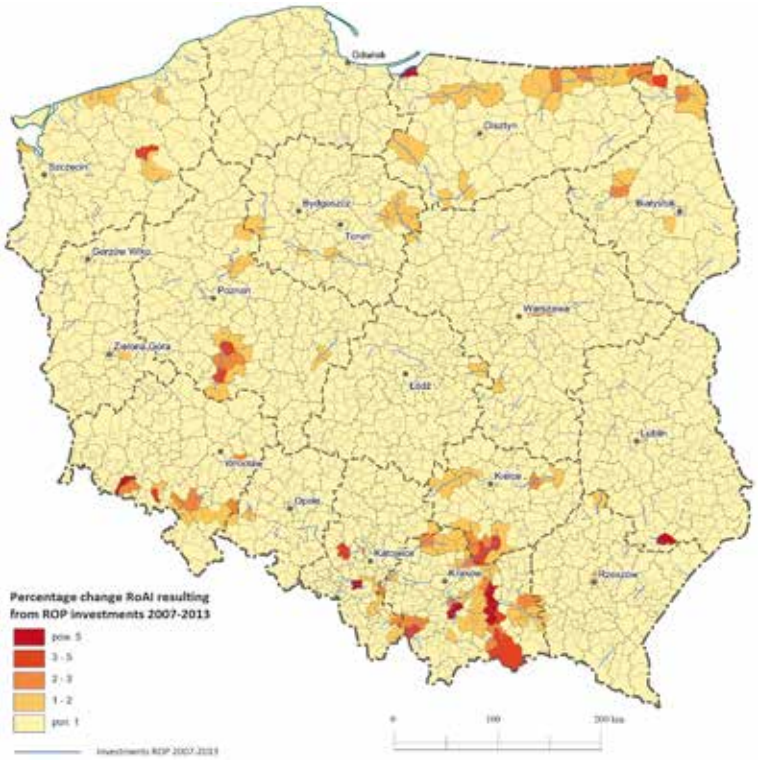

Figure 8. Percentage change in the synthetic Road Accessibility Indicator RoAI as a result of investments co-financed from ROPs in the programming period 2007-2013

Thus the results obtained prove the large importance of informed and timely implementation of regional level road investments. The **transport policies** of some voivodeships have clearly proved more effective than others. This concerns especially the Warmian-Masurian, Kuyavian-Pomeranian, Świętokrzyskie, Lesser Poland and Greater Poland Voivodeships. At the same time, in some regions the effect of road investments under ROPs is practically not visible.

The spatial image of accessibility level changes as a result of **all investments co-financed in 2007-2015 from the European Union funds** (Fig. 9) to a large extent reflects the image for investments under OP I&E.

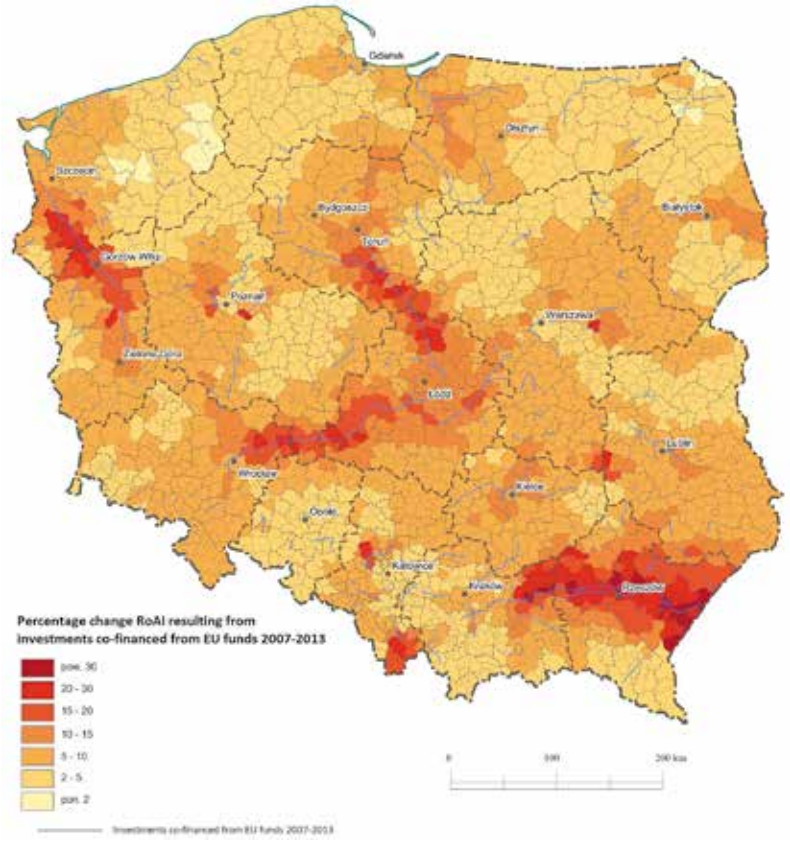

Figure 9. Percentage change in the synthetic Road Accessibility Indicator RoAI as a result of all investments co-financed from the EU funds in the programming period 2007-2013

However, certain differences *in plus* can be observed:

- in the region of the new bridges on the Vistula River (investments under OP DEP);
- in certain areas near the border (with Russia and Belorussia, as well as Slovakia; investments under OP DEP and certain ROPs);
- in voivodeships running investment policies aimed at creating a cohesive network of regional roads (e.g. the Świętokrzyskie, Warmian-Masurian and Kuyavian-Pomeranian Voivodeships);
- in the neighbourhood of certain voivodeship roads that take over part of the traffic between metropolises (e.g. between Wrocław and Poznań); this effect can be deemed transient, since in the subsequent perspective the traffic from such routes will be taken over by newly constructed expressways.

Fig. 10 shows the **share of investments co-financed from European Union funds** in the total accessibility improvement in Poland in **2007-2015**. The picture obtained is strongly differentiated spatially. In a dominant part of Poland, a greater role was played by investments financed from

other sources. This can be a certain surprise, but follows mainly from the location of the sections of concession motorways (especially A1 to Gdańsk) and from financing of the key Łódź-Warsaw section of the A2 motorway directly from the state budget. Its central location and the importance of the capital as a demographic and economic pole had determined the image of the indicator in the entire north-eastern part of Poland. As the mentioned A1 motorway has remained the only so large investment serving northern Poland, the concession investments turned out to be dominant also in the Baltic coast belt. The effects of constructing the western part of A2 (by the Autostrada Wielkopolska company) also contributed to that situation.

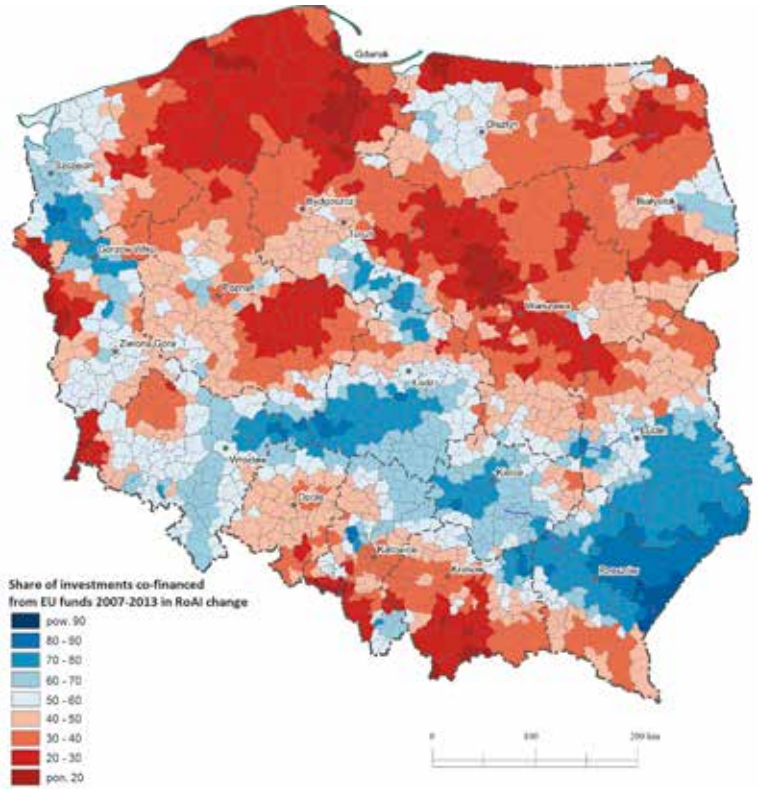

Figure 10. The share of all investments co-financed from the EU funds in the programming period 2007-2013in the RoAI change

As a result, we can only determine relatively limited but also compact zones where the accessibility improvement in 2007-2015 was determined first of all by the European Union support. These are:

- area covering the central and northern Subcarpathia and the southern Lublin region (A4 and S17), plus the belt running from Wrocław through the southern part of the Łódzkie Voivodeship and the northern part of the Silesian Voivodeship up to the Świętokrzyskie Voivodeship (S8 and S7);
- western part of the West Pomeranian Woivodeship (S3);
- narrow belt between Łódź and Toruń (A1);

– western part of the Warmian-Masurian voivodeship (S7).

When assessing the share of EU investments in improving accessibility, we should remember that its reduced level is the result of a certain sequence of undertakings. It brought about simultaneous accumulation of construction of motorways built both in the concession system and from budget funds, including routes located in places of key importance for the whole road system.

The study of accessibility in road transport was supplemented with two additional analyses:

– **road accessibility indicator taking into account destinations outside Poland** in the whole European continent (**RoAIa**),

– **isochronic** analysis, i.e. **cumulative accessibility to population** within the reach of 60- and 90-minute isochrones of access to voivodship cities (the appropriate cities and city networks).

The **road accessibility indicator RoAIa** taking into account destinations outside the country borders was calculated for passenger transport for 2013 and 2023 while adopting appropriate assumptions regarding the waiting time on the external borders of the Schengen zone (see Rosik 2012). The spatial layout obtained is different than in case of the indicators closing on the borders of Poland. The best accessibility areas are located along the Polish-German border, and in a broader approach also along the Polish-Czech border, and motorways A2 (from Świecko to Poznań) and A4 (from Zgorzelec to Górny Śląsk). We can note the visible impact of the "mass" of the Berlin metropolis located outside the country borders, and to a lesser extent also of the densely populated areas in the northern Czech Republic. Among the road routes, the layout map shows mainly motorways. Peripheries in the European sense (areas with the lowest value of the RoAIa indicator) are concentrated in the east of the country, first of all in the Warmian-Masurian and Podlaskie Voivodeships, as well as in the Bieszczady Mountains. The investments to be undertaken in western and central Poland in 2014-2020 will result in spatially proportional improvement in the situation. In eastern and northern Poland, the peripheral zones will be reduced. This applies especially to Pomerania (as a result of constructing expressway S6) and to the central part of the eastern borderland (southern Podlasie and the Lublin region). A large importance will be also gained by the belt along the line of expressways S17 and S19, joining south-eastern Poland to the capital.

The percentage changes in the RoAIa indicator in 2013-2023 (Fig. 12) confirm that the undertaken investments contribute first of all to improvement in communication of the eastern and northern voivodeships with Europe. Large changes occur also along S5 (between Gniezno and Grudziądz), S6 (between Kołobrzeg and Gdańsk), S7 (in its northern part), S61 (Via Baltica) and along the mentioned S17/S19 line. The S17/S19 and S61 roads contribute to better communication with motorway A2, leading out traffic towards West Europe. S61 additionally joins Polish entities to regions and centres of the Baltic States (the effect of absence of barrier on the Polish-Lithuanian border). S6 provides communication of northern Poland with Germany. The same role is played by the northern section of S7, ensuring a connection from Warmia and Mazuria via Gdańsk and S6 towards West Europe. Hence the effect of investments co-financed from the EU funds from the international viewpoint is focused on the peripheral areas of Poland. Improvement

in the RoAIa indicator value in large metropolises will be clearly smaller (compared to the national indicator, as well as compared to previous programming periods). This is a natural consequence of closing certain development stages of the road network and shifting the investments from transit motorways to expressways joining the regions of Poland.

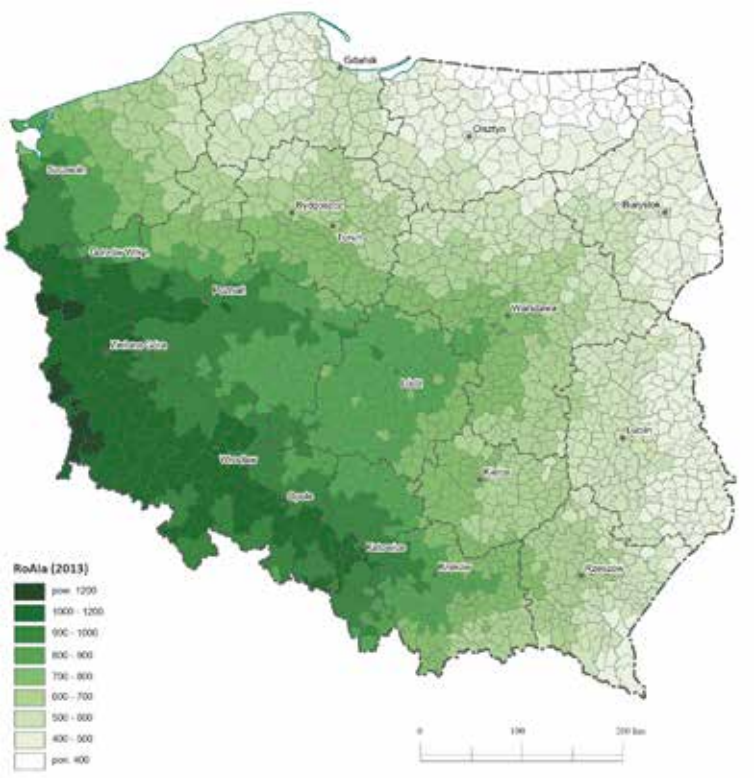

Figure 11. Road Accessibility Indicator RoAIa (passenger transport including destinations abroad) – base value in 2013.

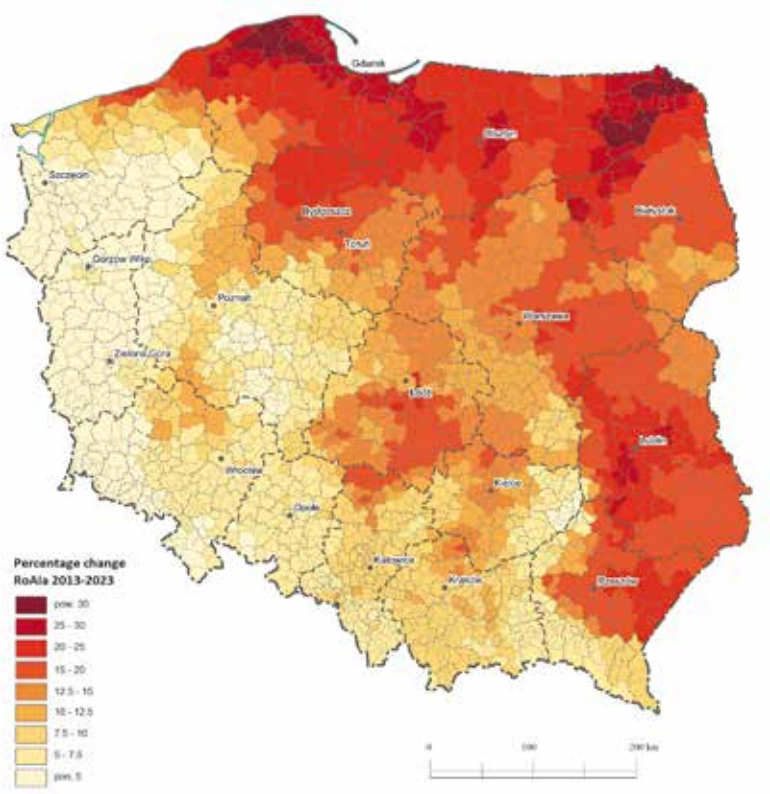

Figure 12. Percentage change in the Road Accessibility Indicator RoAIa (passenger transport, including destinations abroad) in 2013-2023 (assuming implementation of investments according to the state of knowledge as of 2014)

Isochronic analysis. Cumulative accessibility. Cumulative accessibility was analysed for 2013 and 2023 separately with respect to the **60- and 90-minute isochrones**. The 60 minute isochrone is often identified with the labour market range (as a conventional limit value for commuting to work). The 90-minute isochrone is sometimes used in studying accessibility to higher level services, as the time distance corresponding to relatively convenient facultative movements. Both isochrones were used for the needs of the National Spatial Development Conception 2030 (Komornicki et al. 2008).

The analysis conducted in a longer perspective, i.e. up to 2023 (actions planned in the present programming perspective of EU) yields the following result. The largest gains are noted by the voivodship cities that will have new road investments led to them. The country's capitals will get special gains as a result of several expressways being built simultaneously in various directions. Very large "benefits" will also be enjoyed by cities situated along the line of expressway S5, i.e. by Bydgoszcz, Poznań and Wrocław. Considerable gains will also be obtained by Kielce (first of all, as a result of continuation of work on expressway S7) and Katowice (benefiting from the construction of the missing section of motorway A1 to Częstochowa), Gdańsk (construction of expressway S6 towards Szczecin), Cracow (construction of S7 towards Podhale) and Rzeszów (continuation of the construction of expressway S19). The only city where the number of people living within the 60-minute access isochrone will decrease will be Łódź. The reason in this case

is a poor demographic forecast, and the fact that most of the planned investments had been implemented by 2013. Due to the clear increase in the investment efforts in eastern Poland, in spite of the progressing depopulation, the balance will be positive for all voivodeship centres in this macro-region of Poland. We can formulate the thesis about the existence of a periodical compensation for an actual reduction of population by improvement in access to regional labour markets (commuting to work as a substitute for permanent migrations). Such compensation is possible first of all in the period of fast infrastructure development, which will occur in eastern Poland in 2014-2020. After construction of the basic network of road links, accessibility improvement slows down and is no longer able to compensate for the natural and migration-based reduction of population. Were the accessibility improvement factor to play a positive role in stooping the migration processes, the presented reduction (e.g. in the Łódzkie) Voivodeship) can theoretically turn out to be smaller.

The actual spatial range of isochrones is presented in Fig. 13. It shows the areas which are either already included in the isoline of 60-minute commuting to voivodeship cities or will find themselves in that range in 2015 and 2023. The range increase remains invisible where the determined zones of two neighbouring voivodeship cities overlap. As the same time, there are places where the neighbouring metropolises will remain under strong mutual influence, which can take the form of competition (among others, for a commuting employee) or complementary cooperation (two-way commuting). Such a situation is already encountered at present (disregarding voivodeships with two administrative centres) between Cracow and the Upper Silesia conurbation, the Upper Silesia conurbation and Opole, Opole and Wrocław, as well as Warsaw and Łódź. New road investments will make it also occur, among others, between Poznań and Wrocław, Rzeszów and Lublin, Gdańsk and Bydgoszcz, as well as between Cracow and Kielce. At the same time, in 2023 there will still be compact and spatially expanded areas remaining outside the reach of the 60-minute isochrone to the proper voivodeships centre. The greatest of them will be central Pomerania, northern Mazovia, the borderland of the Podlaskie and Warmian-Masurian voivodeships next to the country border, southern Greater Poland, as well as the Carpathian and Sudeten Mountains. This layout is a strong argument for either further expansion of the transport infrastructure towards the capitals of the appropriate voivodeships or reinforcing subregional centres located in those areas.

Table 3. Population within the reach of the 60-minute isochrone by voivodeship cities in 2013 and 2023 (in thou. of inhabitants.)

	Diagnosis		Changes
	2013	**2023**	**2013-2023**
Białystok	692	753	61
Bydgoszcz	1,285	1,568	283
Gdańsk	1,732	1,910	178
Gorzów Wielkopolski	704	869	165
Katowice	5,526	5,806	280
Kielce	952	1,193	241
Cracow	3,822	3,962	140
Lublin	1 230	1 316	86
Łódź	2 050	2 045	-5
Olsztyn	674	749	75
Opole	1,487	1,496	9
Poznań	1,784	2,039	255
Rzeszów	1,323	1,635	312
Szczecin	821	862	41
Toruń	1,668	1,742	74
Warsaw	3,574	3,930	356
Wrocław	1,886	2,070	184
Zielona Góra	834	972	138

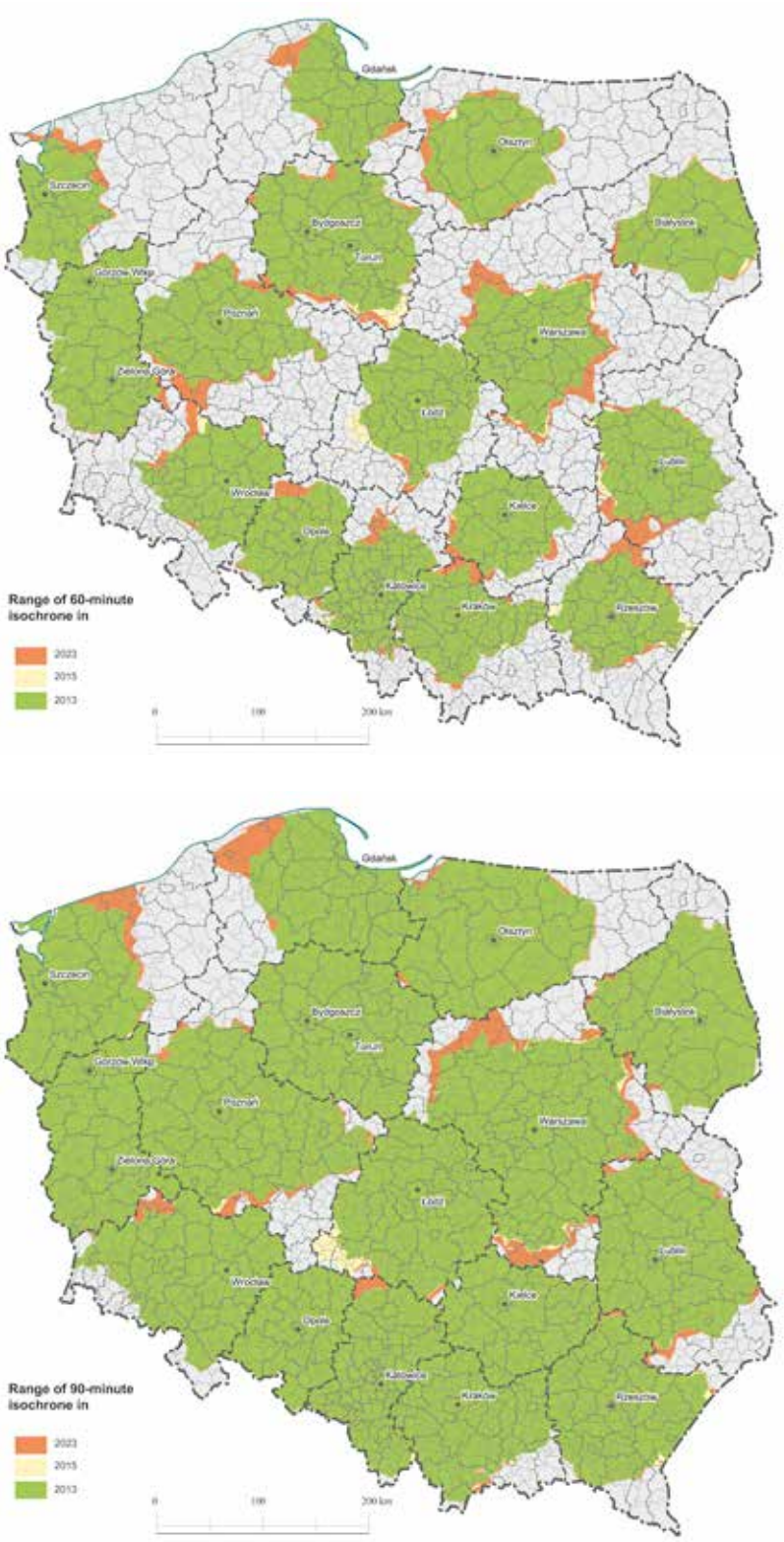

Figure 13. Range of 60-minute and 90-minute isochrones set out from the appropriate voivodeship city in 2013, 2015 and 2023

By 2023, the population inside the 90-minute isochrone will increase most (table 4) in case of Kielce (by over 1.4 M people, first of all as a result of constructing expressway S7 towards Krakow) and Bydgoszcz (here as a clear effect of expressway S5). A characteristic thing is that this time there are no more voivodeship cities whose indicator would be reduced. This is an indirect proof for the fact that the network effect will be achieved in the next perspective, and even regional cities surrounded by depopulating areas and not having many new road investments in their direct neighbourhood will „come closer" to other centres, increasing the conventional base for their services.

Table 4. Population within the reach of the 90-minute isochrone by voivodeship city in 2013 and 2023 (in thou. of inhabitants)

	Diagnosis		Changes
	2013	**2023**	**2013-2023**
Białystok	1,213	1,346	133
Bydgoszcz	2,546	3,708	1,162
Gdańsk	2,673	2,977	304
Gorzów Wielkopolski	1,976	2,623	647
Katowice	7,812	7,921	109
Kielce	2,154	3,576	1,422
Cracow	6,959	7,812	853
Lublin	2,086	2,716	630
Łódź	5,137	6,229	1,092
Olsztyn	1,367	1,626	259
Opole	5,794	5,937	143
Poznań	3,307	4,109	802
Rzeszów	2,532	3,374	842
Szczecin	1,332	1,463	131
Toruń	3,248	3,832	584
Warsaw	5,895	6,885	990
Wrocław	3,984	4,420	436
Zielona Góra	2,180	2,649	469

The image of the spatial range of the 90-minute isochrone from the appropriate voivodeship city and its changes (up to 2023) confirm the theses posed in the foregoing (Fig. 13). Already in 2013 a decisive majority of the country's area was within a 90-minute access to the capital of its own voivodeship. The largest effects of the new road investments can be observed in the areas located far away from the voivodeship capital, i.e. first of all in regions with the largest areas (having the most widespread internal peripheries). This concerns first and foremost the Mazovian Voivodeship (increase in the reach of the 90-minute isochrone, especially in the northern and southern

parts of the region, thanks to the planned construction of expressway S7), as well the West Pomeranian and Pomeranian Voivodeships (in both cases, the effect of constructing expressway S6). In a few other cases, new investments will eventually eliminate the „islands" that up to now have been outside the reach of an 1,5 hour access (e.g. at the northern borders of the Silesian and Lower Silesian Voivodeships and the southern extremities of the Łódzkie Voivodeship). Despite the described changes, in the country area there will still remain compact areas with access to the capitals of their own regions longer than 90 minutes. The largest of them will be located in Central Pomerania, and other extensive ones in the belt from northern Mazovia up to Suwałki, in southern and northern Greater Poland, eastern Lublin region and in the Carpathian Mountains. The layout of most poorly accessible areas (in compliance with the logic of the indicator being described) is again determined by the size of voivodeships, as well as by the geographical location of their capitals (e.g., the large areas outside the 90-minute isochrone in both seaside voivodeships follow from the location of Szczecin and Gdańsk on the western and eastern borderland on their own regions, respectively). Also the course itself of the investments to be implemented is not without its own importance. An example can be the planned expressway S61 (*Via Baltica*), which skips Białystok and Olsztyn, and so does not contribute to improving accessibility of those cities from the peripheral areas of both voivodeships (despite running through those peripheries). The picture obtained also shows which sections of the target network of motorways and expressways (not planned for implementation in the perspective 2014-2020 according to the Implementation Document) could first of all contribute to eliminating areas remaining outside the reach of the isochrone of 90-minute access to their own voivodeship cities. These are first of all expressway S11 (southern and northern Greater Poland), expressway S17 (section up to the border with Ukraine in the south-eastern Lublin region), expressway S10 from Płońsk to Toruń, expressway S12 from Radom to Lublin, as well as motorway A2 (the eastern section running through Polesie Lubelskie and eastern borderlands of Mazovia). Some other areas could get closer to their own regional cities only in case of construction of the routes recorded at present in KPZK 2030. Such routes include e.g. expressway S16 through the Warmian-Masurian Voivodeship, potentially the route from Wrocław to Brno through the Kłodzko Basin, and from the Tarnów region to Nowy Sącz.

In table 5 we can see the comparison of population percentages within both analysed isochrones (with respect to the appropriate voivodship cities) in the examined time sections. One of the elements explaining the low values of the indicator change in some voivodeships (in all or only the earlier time sections) is the failure to cover (as has been the case up to now) with the system of motorways and expressways some relatively large subregional urban centres. As a result, they remain outside the reach of the examined isochrones, influencing in a significant way the percentages assigned to some regions. This applies e.g. to the Greater Poland Voivodeship (Kalisz position), West Pomeranian (Koszalin), Pomeranian (Słupsk), Lower Silesian (Jelenia Góra), as well as Mazovian (Płock and Ostrołęka) and Lesser Poland (Nowy Sącz) Voivodeships. At the same time, this is an indication what investments (covering the mentioned cities) could relatively easily improve the indicator value in the mentioned voivodeships.

Table 5. Percentage of population within the reach of the isochrone to the appropriate voivodeship city (by voivodeship)

	60-minute isochrone		90-minute isochrone	
	2013	**2023**	**2013**	**2023**
Lower Silesian	56.5	59.8	86.0	89.0
Kuyavian-Pomeranian	90.6	94.2	100.0	100.0
Lubelskie	56.7	61.4	82.7	84.4
Lubuskie	92.4	93.6	100.0	100.0
Łódzkie	77.8	81.0	95.4	98.8
Lesser Poland	71.7	74.2	90.8	92.5
Mazovian	63.8	68.5	84.8	91.7
Opolskie	84.0	86.9	99.8	100.0
Subcarpathian	61.9	70.1	96.1	96.9
Podlaskie	57.9	62.2	86.9	87.6
Pomeranian	69.9	73.7	84.6	91.5
Silesian	81.2	87.3	99.1	99.8
Świętokrzyskie	70.6	73.7	99.9	99.9
Warmian-Masurian	45.9	49.5	79.7	82.5
Greater Poland	49.9	55.7	78.2	81.7
Zachodniopomorskie	47.3	50.2	64.7	71.9
Poland	66.9	71.2	88.8	91.7

The layout of the motorway and expressway network can be evaluated not only from the national, but also from the intra-regional viewpoint. Due to investments in fast traffic routes, part of voivodeship cities are becoming the main transport nodes of their own regions, which will favour their internal cohesion and synergic effects following from the most effective model of the transport and settlement network in the regional scale. Unfortunately, for a certain part of voivodeship cities the adopted solutions are not optimal from the viewpoint of internal demand, and the cities remain to a certain degree "off the beaten track" since the investments implemented in their area serve rather countrywide or international purposes (e.g. expressway S61 in the Podlaskie and Warmian-Masurian Voivodeships).

Cumulative accessibility of the voivodeship cities network from peripheral areas. A separate issue is cumulative accessibility to the whole network of voivodeship cities. In this case, it is irrelevant what city can be reached in 60 or 90 minutes. In case of the 60-minute isochrones (Fig. 14), we observe better access for the year 2023 in the northern part of the Lower Silesian Voivodeship (the range of one-hour access to Zielona Góra rather than Wrocław), southern Greater Poland Voivodeship (better access to Wrocław than to Poznań), southern Mazovian Voivodeship (better access to Kielce than to Warsaw), and in the western part of Warmia (which is already now within

the range of faster access to Gdańsk than to Olsztyn). In 2023 the construction of expressways in Mazovia will also bring some peripheral communes of the region within 60-minute access to Olsztyn (the effect of implementing investments on expressway S7), Białystok (continuation of the construction on expressway S8) and Lublin (expressway S17). The results obtained can be interpreted in the context of adequacy to the administrative division and membership of some larger cities in the labour markets of the adjacent voivodeships. Despite the obviously different situations in the largest (in terms of area) Mazovian and Greater Poland Voivodeships (which can with time result in their peripheral areas being attracted to the neighbouring voivodeships, along with the infrastructure development), a noteworthy situation in this context is that of the western part of the Warmian-Masurian Voivodeship (with Elbląg), which clearly remains with the influence range (including the labour market range) of Three-City.

Much greater differences in both spatial layouts are noted in case of the 90-minute isochrone. The referral to the whole network of voivodeship cities eliminates virtually all "islands" of bad, i.e. over 90-minute long, accessibility to regional centres inside the country. However, we can still see, in an almost unchanged shape, the largest territories of poor accessibility located on the perpheries (Central Pomerania, eastern Masuria and the Suwałki region, southern Podlasie, south-eastern Lublin region, Carpathian and Sudeten Mountains). In their case situation improvement can only be effected through new road investments.

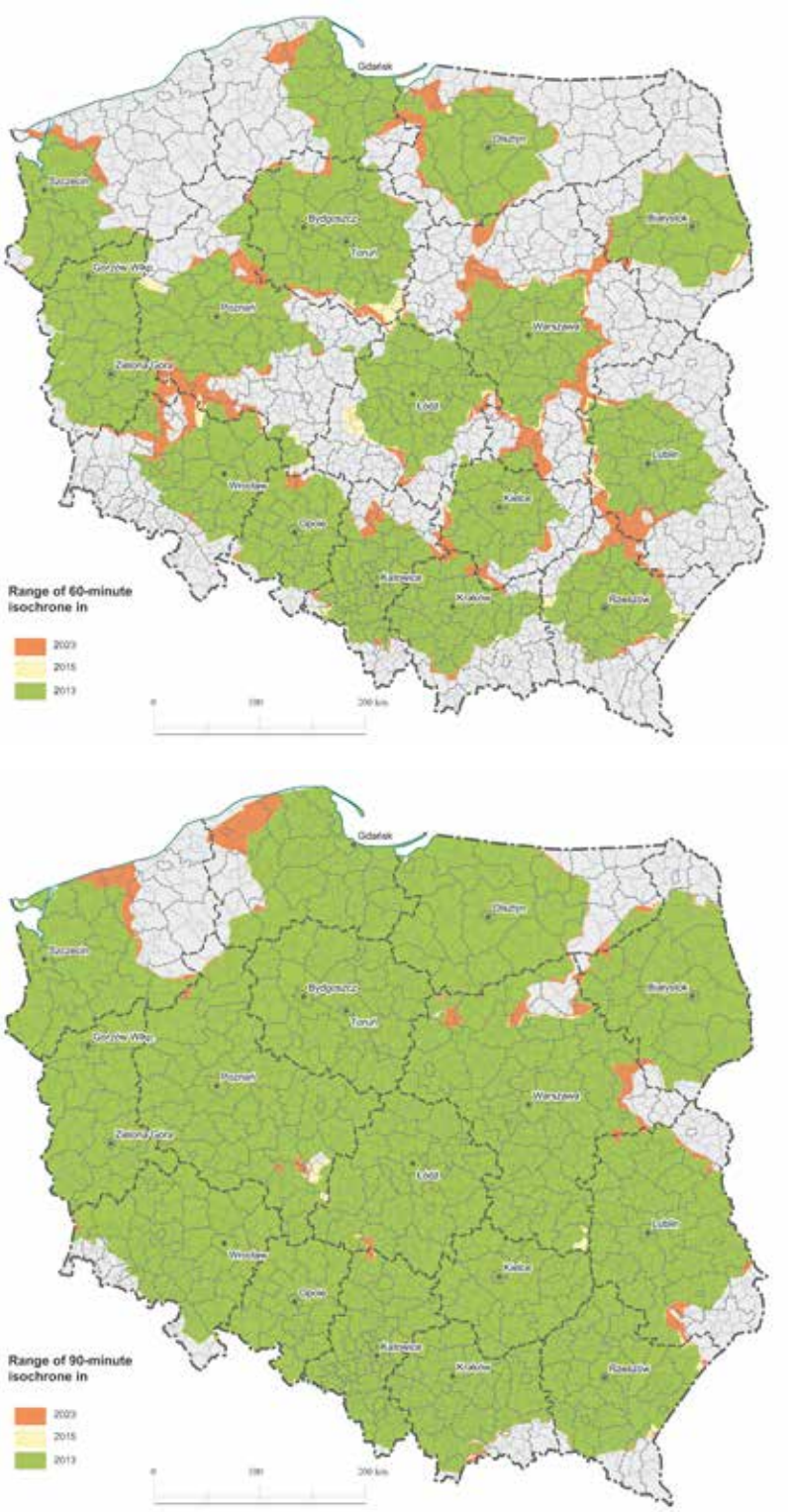

Figure 14. Range of 60-minute and 90-minute isochrones set out from the nearest voivodeship city in 2013, 2015 and 2023

The interpretation of both layouts (in case of either isochrone) may be different depending of the actual destinations we are interested in. Generally, the time of travel to the „own" voivodeship centre is appropriate in case of movements to public utility services in a broad sense with strong administrative setting (public administration, zoned services, such as courts, part of health care). In case of other higer rank services, as well as with respect to labour markets, a more appropriate choice will be the time of travel to an arbitrary closest voivodeship centre (tab. 6).

Table 6. Percentage of population within the range of the isochrone to the appropriate voivodship city and to the network of voivodship cities in the countrywide scale

		Population within the range of isochrone			
		60-minute isochrone in the year		90-minute isochrone in the year	
		2013	2023	2013	2023
The appropriate voivodship city	in thousands	25,761	27,085	34,186	34,908
	% of country population	66.9	71.2	88.8	91.7
Network of voivodship cities	in thousands	26,556	28,399	35,883	36,181
	% of country population	69	74.6	93.2	95.0

The results obtained show unequivocally what areas in the country remain outside both the studied isochrones, at present as well as in the 2023 perspective. In case of the hourly isochrone, the possibilities of its further extending by way of transport investments are limited. Consequently, in some areas, an alternative objective of the territorial policy must be reinforcing of the subregional labour markets. In case of 90-minute isochrone and its related accessibility to higher level services, the situation is less clear. The study has shown that in many cases accessibility can be increased by way of deregulation (de-zoning) of some services. In case of some other compact and poorly accessible territories, subregional centres may be strengthened in their role of service centres, while for some others the best solution seems to be expansion of the road infrastructure.

4.2. Railway indicator RaAI

In railway transport, similarly to road transport, the best accessible areas of the country are the Warsaw and Upper Silesian poles. Belts of better accessibility along the main lines of interagglomeration significance are clearly marked. At the beginning of **2007**, aside of areas with the best railway accessibility, further positions were occupied by the following voivodeships: Łódzkie, Lesser Poland and Opolskie. In the case of Lesser Poland, long travel times via railway transport

between Cracow and Katowice result in a large difference in accessibility between Lesser Poland and Upper Silesia. This difference is much bigger in railway transport than in road transport. By contrast, the voivodeships of Eastern Poland (except for Świętokrzyskie), Lubuskie (primarily as a result of the low railway accessibility of Zielona Góra and Gorzów Wielkopolski) and East Pomerania are among the worst accessible voivodeships. The clearly least accessible one is the Podlaskie Voivodeship (Fig. 15). By **2023** the situation will have changed significantly. Investments executed in the programming period 2014-2020 (according to the state of knowledge as at the middle of 2014) will result in a significant speed increase on the majority of railway lines. The RaAI indicator value (45.25) will exceed the level of the RoAI indicator (41.88) by over 8%, which means that, in light of the adopted methodology, the weighted average of domestic railway accessibility in Poland will be higher than the analogous indicator for road transport. Also on the voivodeship level, in the majority of voivodeships (with the exception of Subcarpathia) railway accessibility will be higher than road accessibility in 2023. The best situation will still occur in the Masovian and Silesian Voivodeships, but the difference in railway accessibility between them will not be as large as in 2007. This stems primarily from the implementation of numerous railway investments in Upper Silesia (including those leading freight traffic out of this area) that will, to a high degree, improve its accessibility. By 2023 the railway accessibility of the Lubusz Voivodeship will have improved significantly (among others, thanks to improving the operation of the so-called Nadodrzanka route). By contrast, the accessibility of the Warmian-Masurian Voivodeship will not grow as quickly and this voivodeship, together with Western Pomerania and Podlasie, will be one of the three worst accessible voivodeships in Poland in 2023. In 2023 areas of worse accessibility between agglomerations, the so-called internal peripheries, are still visible, but in some places they are clearly reduced, e.g. thanks to the planned rapid connection between Płock and Warsaw (Fig. 16).

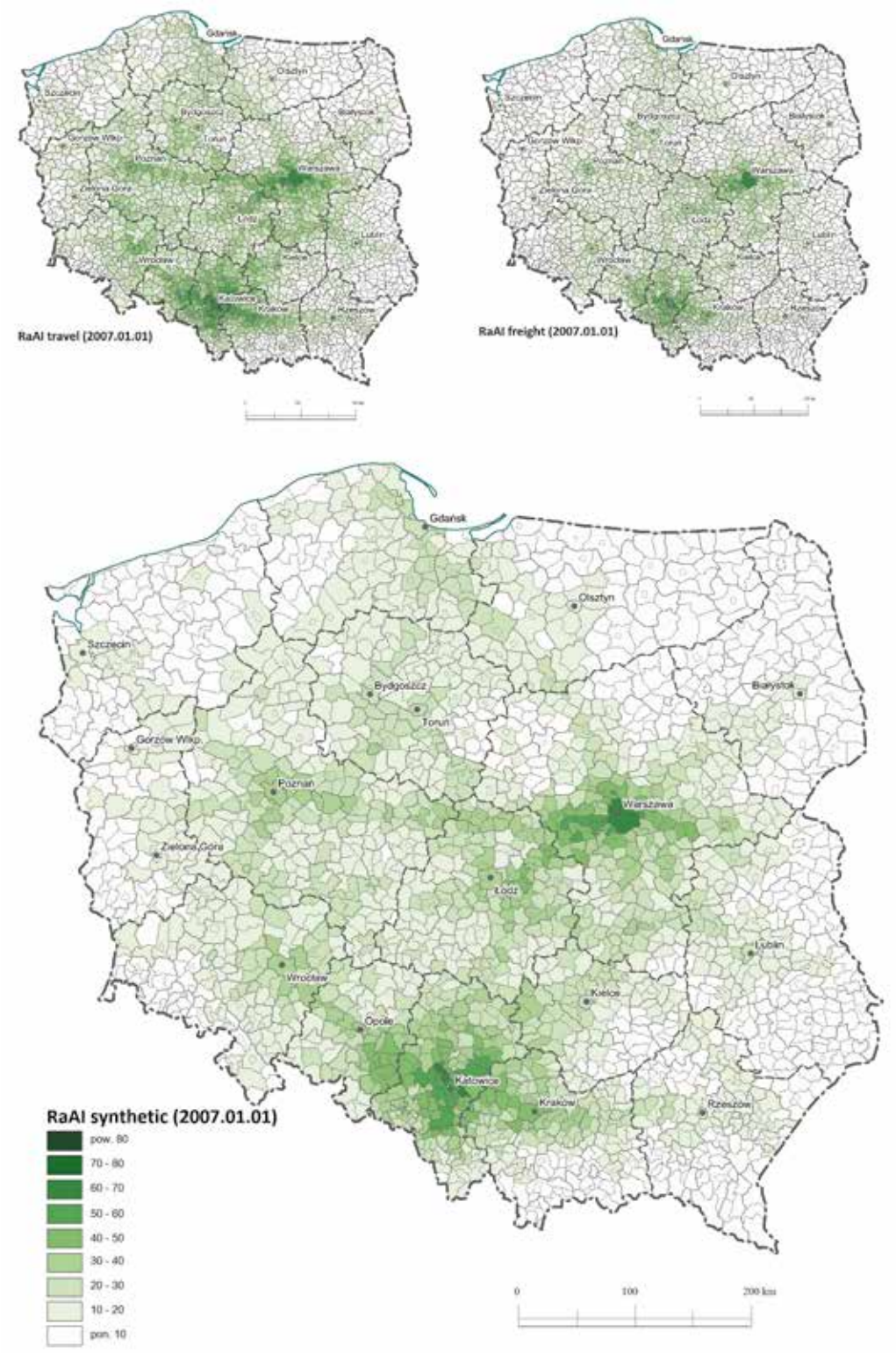

Figure 15. Railway Accessibility Indicator RaAI (passenger, freight and synthetic) – value as at 2007.01.01

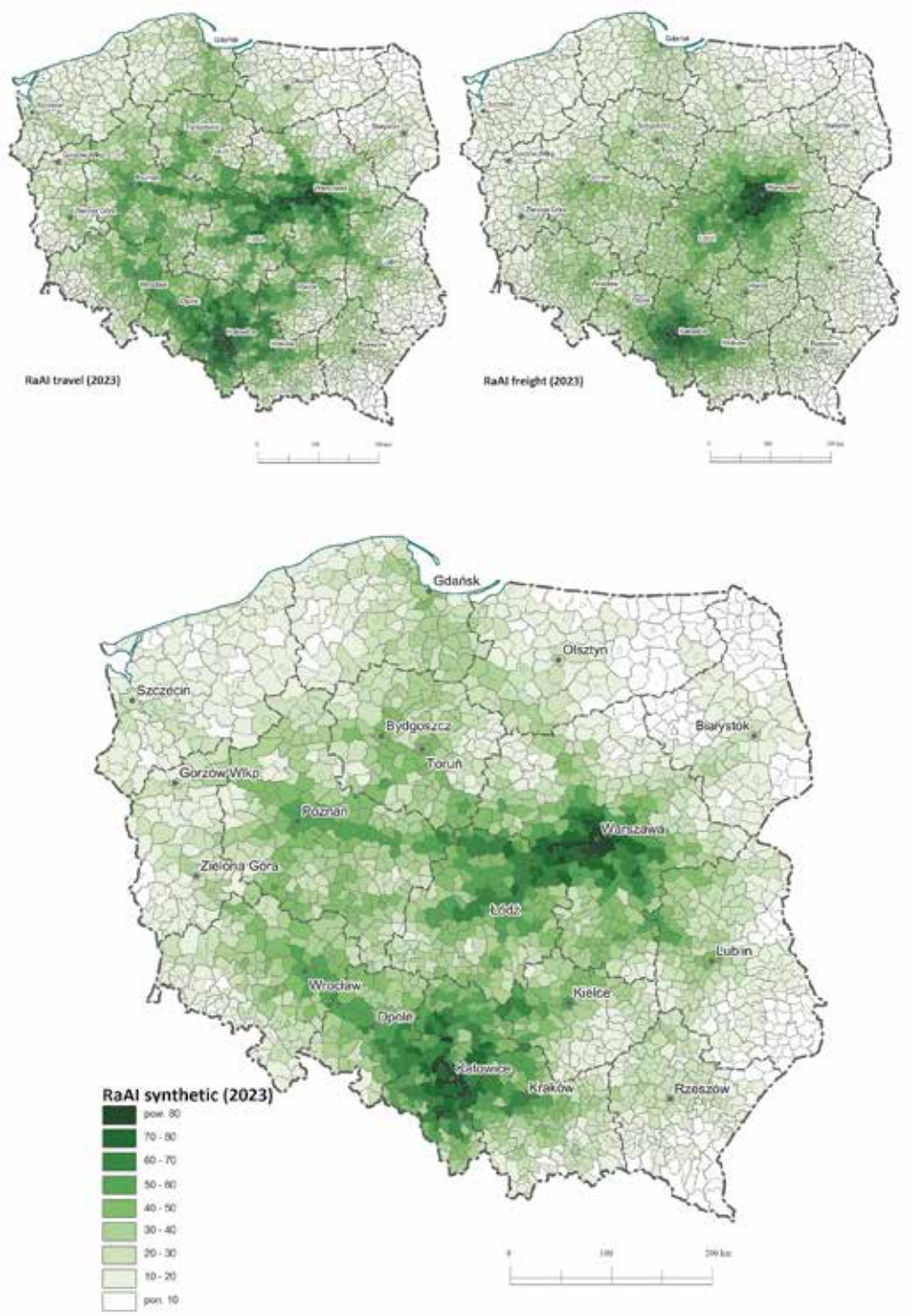

Figure 16. Railway Accessibility Indicator RaAI (passenger, freight and synthetic) – value as at 2023 (assuming the implementation of investments according to the state of knowledge as at the middle of 2015)

In **2007-2015**, in the **percentage** view, areas of accessibility improvement are mosaic (island) in nature, and are related much more to individual investments, also those implemented on networks using sources outside of the European Union (such as, for example, between Białystok and Czeremcha). Improvement in railway accessibility will be noticeable not only in areas which were the best accessible ones already in 2007 (Central and Southern Poland), but also, and maybe primarily, in certain peripheral areas of the country. The biggest beneficiary will no doubt be the Lubelskie Voivodeship, where the improvement in railway accessibility stems both from investments co-financed by the European Union (northern part of the voivodeship) and other speed increases (including restoration of passenger traffic) undertaken as a result of PKP PLK work (the southern part). The next largest beneficiary are a group of voivodeships in Northern Poland (with the exception of Western Pomerania and Podlasie) and also the Subcarpathian Voivodeship, where the accessibility improvement effect stems both from the implemented European Union investments and other investments (e.g. between Rzeszów and Ocice). By contrast, the smallest changes in railway accessibility (only slightly above 7%) are exhibited by the Lesser Poland Voivodeship (Fig. 17).

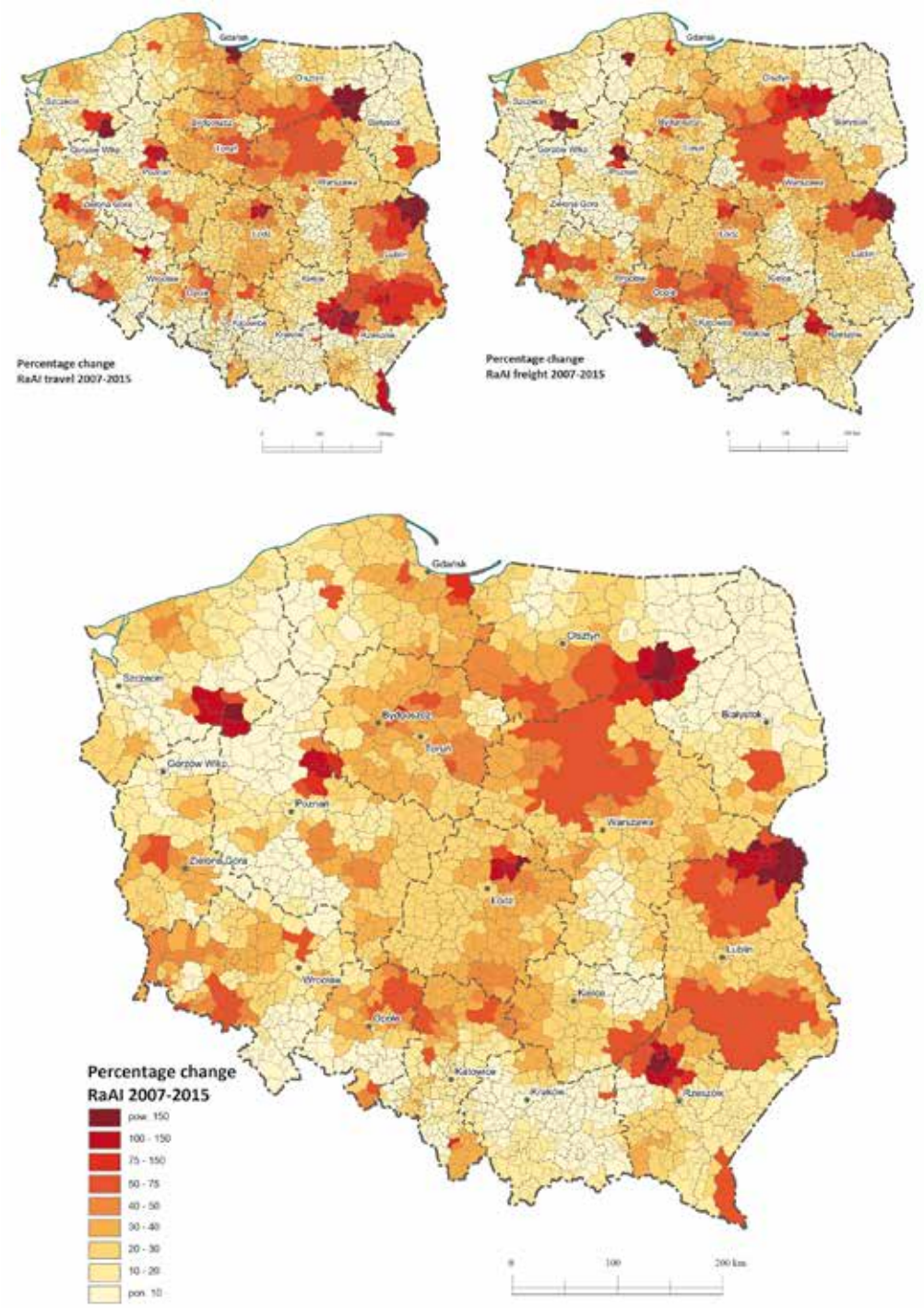

Figure 17. Percentage change in the Railway Accessibility Indicator RaAI (passenger, freight and synthetic) in 2007-2015

The largest railway investments in the programming period 2007-2013 were the result of the **Operational Programme Infrastructure and Environment**. Thanks to railway investments implemented as part of OP IE 2007-2013, railway accessibility in Poland will increase by 4.85% (net effect). The biggest beneficiaries are the Opolskie and Warmian-Masurian Voivodeships. On the other hand, the effects are marginal in the Subcarpathian Voivodeship (increase by only 0.4%). It is worth noting that investments implemented as part of OP IE 2007-2013 form long strings and are clearly concentrated in three areas of the country. Thanks to these investments, railway accessibility increases significantly within two triangles, i.e. between Warsaw, Gdynia and Bydgoszcz and between Łódź, Katowice and Zielona Góra. Large accessibility increase is also noticeable east of Warsaw, in the direction of Terespol (Fig. 18).

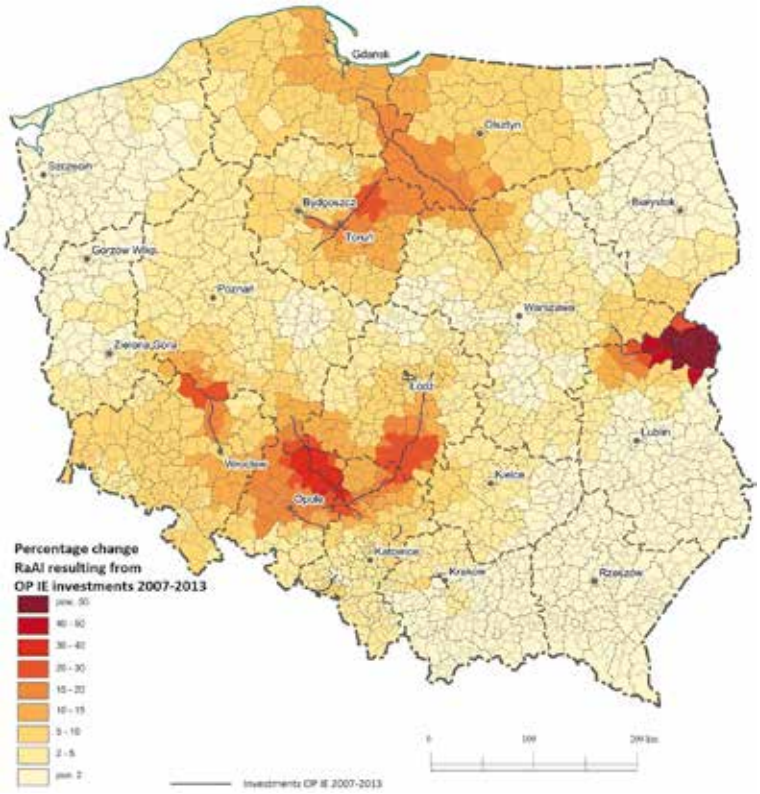

Figure 18. Percentage change in the synthetic Railway Accessibility Indicator RaAI as a result of investments co-financed from OP IE in the programming period 2007-2013

No railway investments were implemented as part of the **Operational Programme Eastern Poland** in the programming period **2007-2013**. An important factor for the local improvement in railway accessibility were, however, investment activities financed from **Regional Operational Programmes**. Thanks to railway investments implemented as part of ROPs, the railway accessibility in Poland increased by 1.09% (net effect). The biggest beneficiaries were the following voivodeships: Lubusz (accessibility increase by 6.92%) and Subcarpathia (increase by 4.94%). On the other hand, the effects were almost unnoticeable in the Podlaskie (increase by 0.25%), Opolskie (increase by 0.13%) and Silesian (increase by 0.1%) Voivodeships. No linear ROP investments

were observed in the Silesian and Świętokrzyskie Voivodeships, and only short sections were constructed in Lower Silesia and Lesser Poland (Fig. 19).

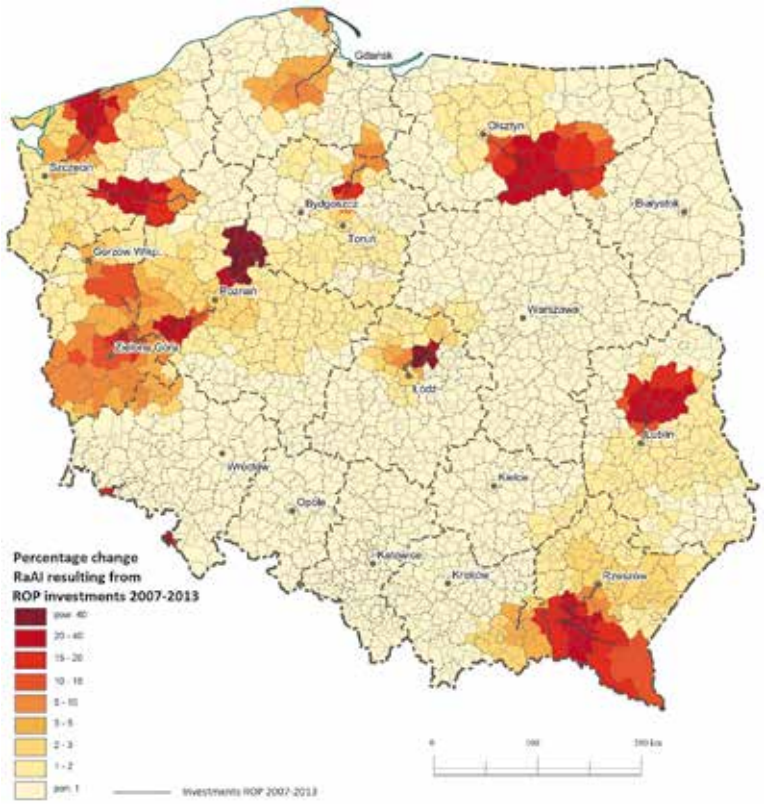

Figure 19. Percentage change in the synthetic Railway Accessibility Indicator RaAI as a result of investments co-financed from ROPs in the programming period 2007-2013

Taking into account **all investments co-financed from European Union funds in the programming period 2007-2013**, their total net effect on railway accessibility change in this period was almost 6%. For obvious reasons, the OP IE fund had the greatest impact. Investments implemented as part of OP IE and ROPs were, in spatial presentation, complementary to a high degree, and supplemented the image of railway accessibility improvement in Poland. Here the exceptions were the Podlaskie and Lesser Poland Voivodeships, which exhibited the lowest percentage accessibility change as a result of railway investments co-financed from European Union funds. Areas with small accessibility changes included also the Southern Masovian and Świętokrzyskie Voivodeships, and the area where the Lubelskie and Subcarpathian Voivodeships meet. On the other hand, the biggest beneficiaries (accessibility increase by over 10%) are the Opole, Warmian-Masurian, Pomeranian and Kuyavian-Pomeranian Voivodeships. In case of the Opolskie Voivodeship, this is almost exclusively the effect of OP IE (lines 272 and 143), but in the other three voivodeships it is the combined effect of investments implemented as part of OP IE and ROPs (Fig. 20).

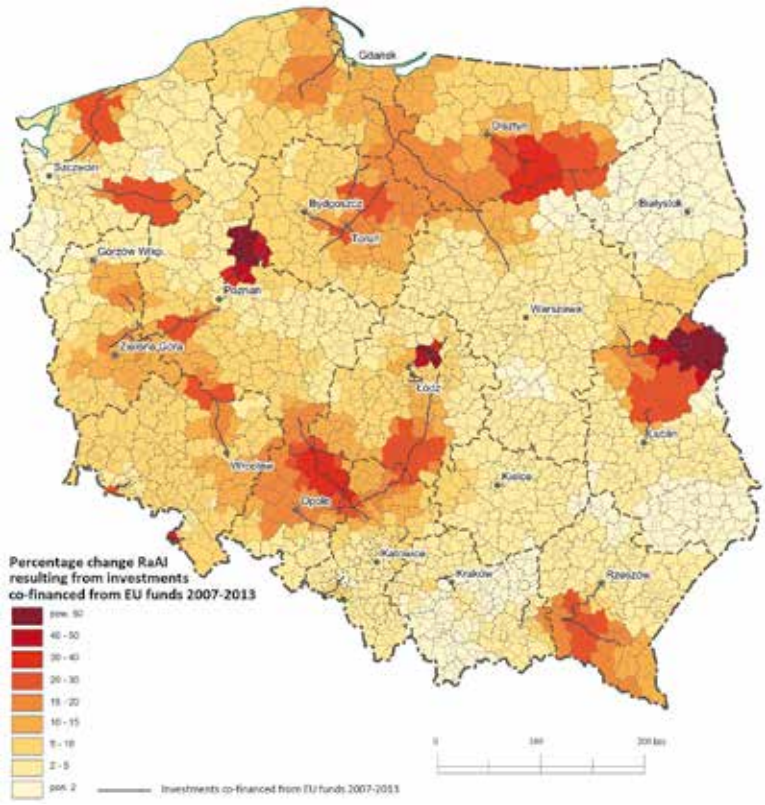

Figure 20. Percentage change in the synthetic Railway Accessibility Indicator RaAI as a result of all investments co-financed from European Union funds in the programming period 2007-2013

The contribution of investments co-financed by the European Union in the programming period **2007-2013** to the entire accessibility changes taking place from the beginning of 2007 until the end of 2015 is difficult to analyse on the commune level. In certain communes, a decrease in railway accessibility was noted as a result of line closures or speeds limitations on the railway network maintained by PKP PLK. On the voivodeship level, however, the accessibility indicator RaAI value increased, thus an analogous study may be conducted as a result of the aggregation of results. The contribution of investments co-financed by the European Union to railway accessibility change is very diversified (from 12% to 83%). The voivodeship where European Union investments contributed the most to increasing railway accessibility was Opole (83%), while the lowest contribution of these investments occurred in Podlasie (16%) and Mazovia (12%). In Mazovia, the contribution of GDP growth and investments implemented from other sources and those completed in the previous programming period 2004-2006 was significant, while in Podlasie such a low indicator value is mainly the effect of the lack of European Union investments (Fig. 21).

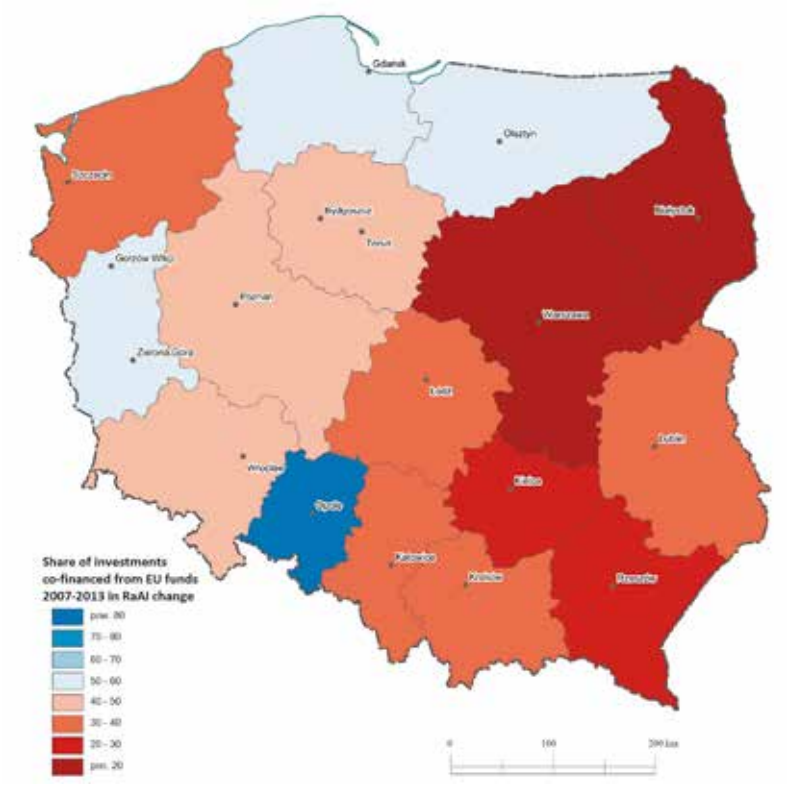

Figure 21. Contribution of all investments co-financed from European Union funds in the programming period 2007-2013 to the RaAI change

4.3. Air indicator AAI

Accessibility to airports (AAI) is calculated based on different methodological assumptions than road accessibility (RoAI) and railway accessibility (RaAI). The source of data concerning masses is not the population or GDP, like in case of roads and railway, but **airport capacity**. From the dynamic viewpoint, air accessibility changes are affected by changes in airport capacity and improvements in vehicle access to airports using road transport.

The spatial distribution of air accessibility in Poland is determined by the location of two airports in Mazovia, i.e. the capacity of the Warsaw Okęcie airport (and, to a lesser degree, the new Warsaw Modlin aiport), as well as by the road system providing access to the most important airports. This means that the best accessibility is in the vicinity of the capital metropolis and in the A2 (from Poznań to Warsaw) and A4 (from Wrocław to Cracow) road belts, with a "peak" of accessibility between Katowice and Cracow (in 2015, airports in Pyrzowice and Balice already had the highest capacity after the airport in Warsaw). Furthermore, Pomerania was an "island" of better accessibility (Fig. 22). In 2023, the significant improvement air accessibility stemmed from a series of investments implemented in airports (primarily in the programming period 2007-2014), as well

as the improvement in access to these airport as a result of road investments on motorways and expressways. Thus, in 2023, the two poles of best accessibility: Mazovia and Cracow-Upper Silesia merge together, creating an area of perfect air accessibility. On the other hand, the West Pomeranian Voivodeship is characterised by the worst air accessibility in the country (the proximity of airports outside the territory of Poland was not taken into account) (Fig. 23).

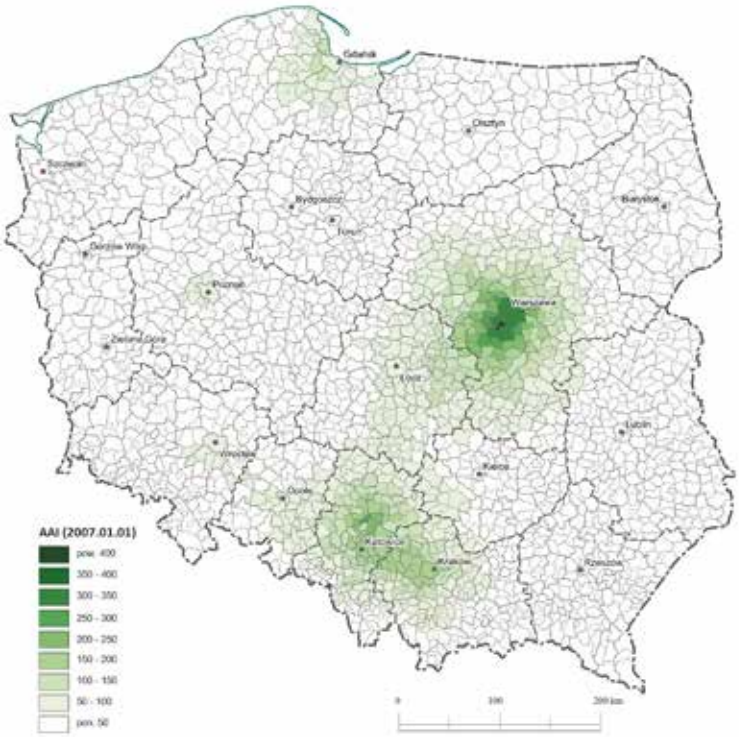

Figure 22. Air Accessibility Indicator AAI – in 2007 and in 2023

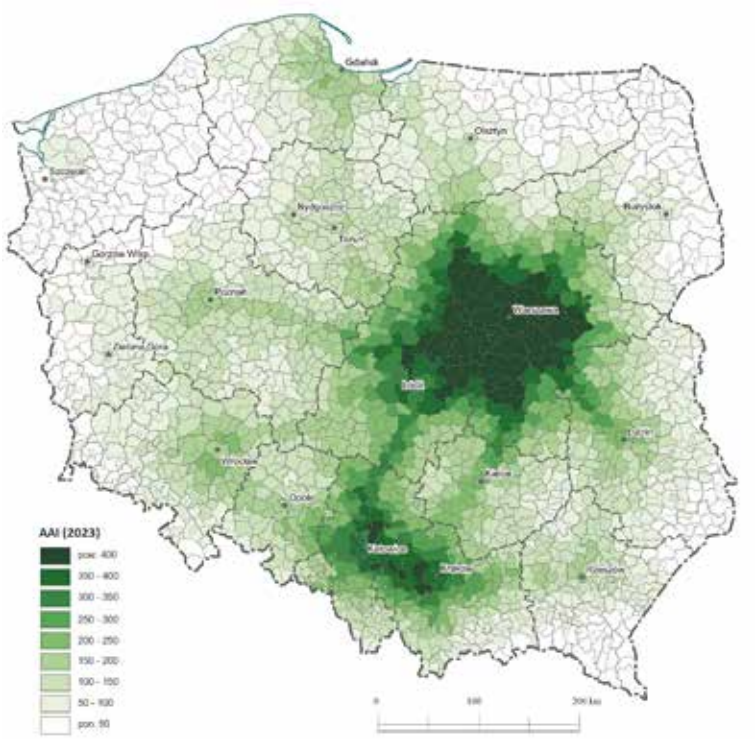

Figure 23. Air Accessibility Indicator AAI – in 2023

In 2007, there were no airports in Lublin and Modlin. The capacity of the largest airports in the country was at least twice, and in certain cases several times, lower in 2007 than at the end of the programming period 2007-2013. The total estimated capacity of airports in Poland grew in the programming period 2007-2013 more than twice (from about 25 M passengers annually to about 58 M). Taking into account the aviation market dynamics in Poland and the total number of passengers serviced in 2014 – about 27 M – points at the conclusion that investments completed by 2015 meet the demands up to around 2030. Vehicle access to airports in 2007 was also hindered by the lack of motorways on most access routes. Due to numerous infrastructural investments, both at the airports themselves and on access routes to the airports, airport accessibility increased significantly in the programming period 2007-2013. In percentage terms, Eastern Poland benefited the most (over threefold AAI indicator increase), including in particular the Lubelskie and Podlaskie Voivodeships, primarily as a result of the launch of new airports in Lublin and Modlin. A significant beneficiary was also the Kuyavian-Pomeranian Voivodeship, mainly thanks to the completion of the northern section of the A1 motorway, but also as a result of increasing the capacity of the Bydgoszcz airport (over fourfold increase in the AAI indicator value).

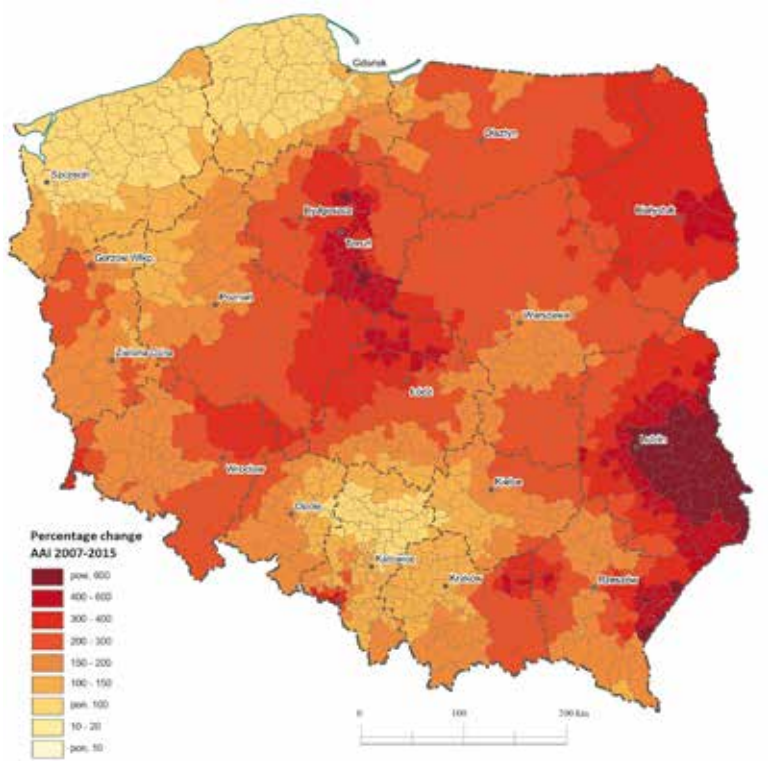

Figure 24. Percentage change in the Air Accessibility Indicator AAI in 2007-2015

The area where the indicator changed only slightly was Central Pomerania. It is an area geographically distant from the closest airports and, at the same time, deprived of large road investments in 2007-2015. From the voivodeship viewpoint, air accessibility improved the most in the Masovian and then the Łódź Voivodeships. Large increases occurred in the Lesser Poland and Silesian Voivodeships, while the Western Pomeranian Voivodeship definitely benefited the least. No investments improving airport capacity co-financed from European Union funds were provided for implementation in the programming period 2014-2020. Air accessibility changes in 2013-2020 stem from the ending investments planned in the programming period 2007-2013 and from a planned investment most likely executed from other sources, i.e. the necessary expansion of the Modlin airport. A significant improvement in air accessibility in many areas will occur mainly as a result of road investments. In view of the clearly shortening travel time to the already operating airports, the construction of further airports may give rise to substantial doubts.

The conducted study confirms the thesis that accessibility improvement in air transport may be achieved both through erection and modernisation of airport infrastructure (new facilities, capacity increase) and by developing land (both road and railway) transport. This is why large AAI increases may occur in areas distant from airports. It is a premise for critical reflection on the purposefulness of undertaking certain new investments in the form of erecting airports. Their possible creation has to be evaluated taking into account activities in other transport modes. This in particular applies to investments relatively not distant from the Mazovian system of airports. It seems that an argument for erecting new structures may be the lack of capacity of the already existing airports, not the rapidly changing temporal distance for travelling to them.

4.4. Inland water indicator WIAI

Similarly to air transport, water inland accessibility (WIAI) is calculated based on different methodological assumptions than road (RoAI) and railway (RaAI) accessibility. The source of data concerning masses is the **class** of **water route** sections. Due to methodological reasons, the water route class of sections adjacent to a river port was assigned to river ports. Heavy goods transport access to all the existing and planned river ports was enabled. Thus, from the dynamic point of view, changes in water inland accessibility are influenced by changes in water route classes resulting from investments on water routes and improvement in vehicle access to inland water ports using heavy goods transport as a result of investments in the road network.

The spatial distribution of water inland accessibility was and is determined in Poland by the water route classes on the individual sections of the Odra Waterway (class II on most of its length, class III in sections, with the exception of the section between Widuchowa and the Baltic Sea, where the fifth waterway class operates) and the road system providing access to the most important river ports (the analysis highlights 14 ports on the Odra river and 9 ports on the Vistula, Martwa Wisła and Nogat Rivers, as well as in Elbląg). This means that the best accessibility is present in places with the highest waterway class (lower Odra) and the highest density of river ports (central section of Odra, lower section of Vistula). Water inland accessibility decreases while moving away from Odra and lower Vistula (Fig. 25).

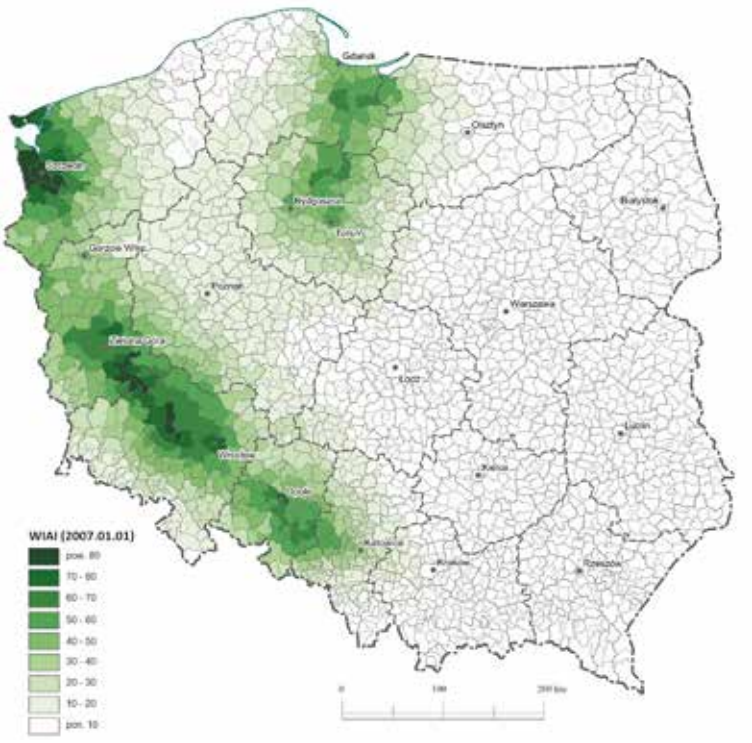

Figure 25. Water Inland Accessibility Indicator WIAI – in 2007 and in 2023

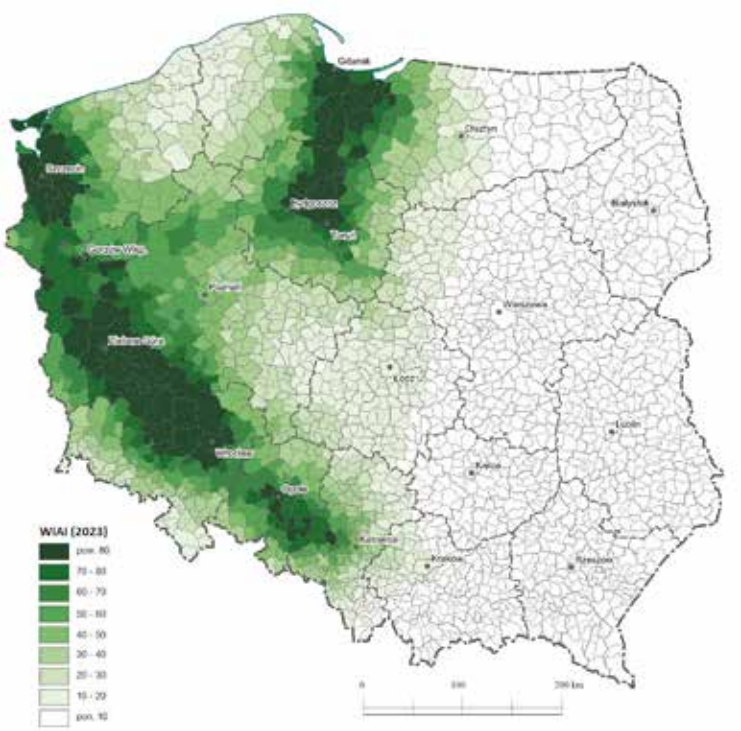

Figure 26. Water Inland Accessibility Indicator WIAI – in 2007 and in 2023

In percentage terms (Fig. 27), in **2007-2015** a beneficiary is, paradoxically, the area of south-Eastern Poland, with the particular emphasis on the Subcarpathian Voivodeship, which stems from the effects of the very low base of accessibility to river ports in 2007, relatively few investments on inland waterways (spot investments on the Odra Waterway) and the significant improvement in HGV transport access to those ports from Eastern Poland via the A4 motorway in 2007-2015. Change in the situation until **2023** will stem primarily from the planned water investments, including opening of river ports on Noteć, as well as the planned modernisation of the water class of Odra (to class three on the majority of its length) and Vistula (improvement to class two, and locally three), as well as the improvement in the road infrastructure condition.

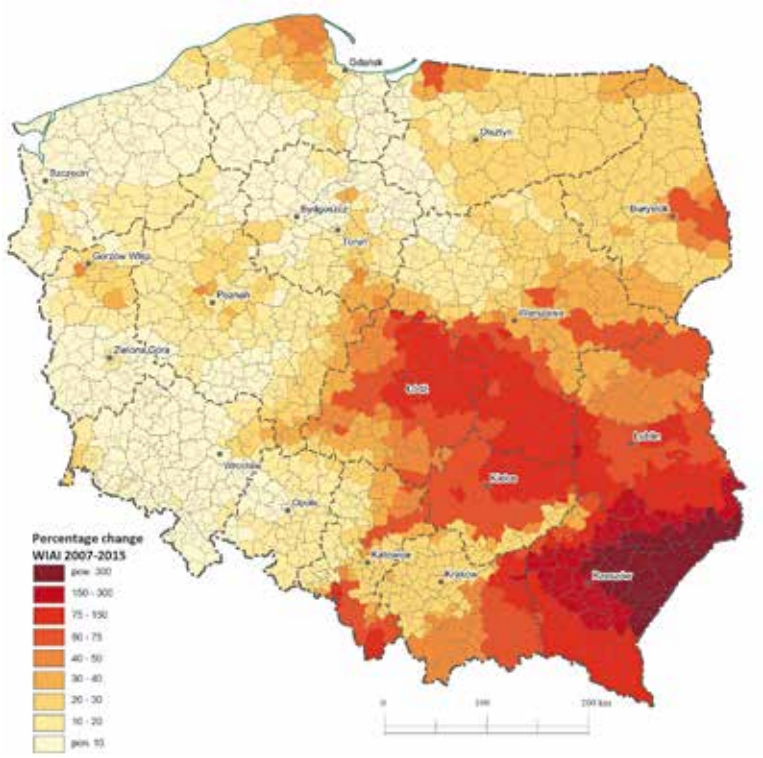

Figure 27. Percentage change in the Water Inland Accessibility Indicator WIAI in 2007-2015

4.5. Synthetic indicator MAI

The contribution of modal indicators on the commune level in the total MAI passenger or freight indicator value is analogous to the contribution of individual transport modes to passenger or freight transport. By the same token, the MAI indicator value is to a large extent determined by the road indicator RoAI value (especially in passenger transport). The remaining part of the indicator is mostly explained by railway transport. This is why what deserves special attention are places in Poland where, despite such established assumptions, improvement in the MAI indicator value is clearly caused by railway investments. In special cases, primarily in Mazovia, the indicator value is influenced by air transport (Fig. 28).

Changes in the synthetic MAI indicator confirm the key role of certain investments for the country's entire transport system and for the accessibility level of vast territories. This applies first of all to certain motorway sections (in particular the central fragment of A1), but also to modernised railway lines, where the speed increased significantly (like the Warsaw-Gdańsk line), or whose location in the network was of special importance for accelerating inter-agglomeration connections (like the Częstochowa-Opole line). Investments located on the peripheries (both road and railway investments) cause the greatest percentage accessibility improvement, but with a limited

territorial reach. This is caused by the following, often overlapping effects: border location (one travel path from the entity to the majority of the remaining entities in the country) and low base (very low initial indicator level). At the same time, investments located in the centre provide a greater network effect and participate in a greater number of intercommunal connections. Even if percentage increases in MAI in individual communes are not spectacular in central Poland (the high base effect), their results are visible over much larger areas, sometimes distant from the investment itself (Fig. 30).

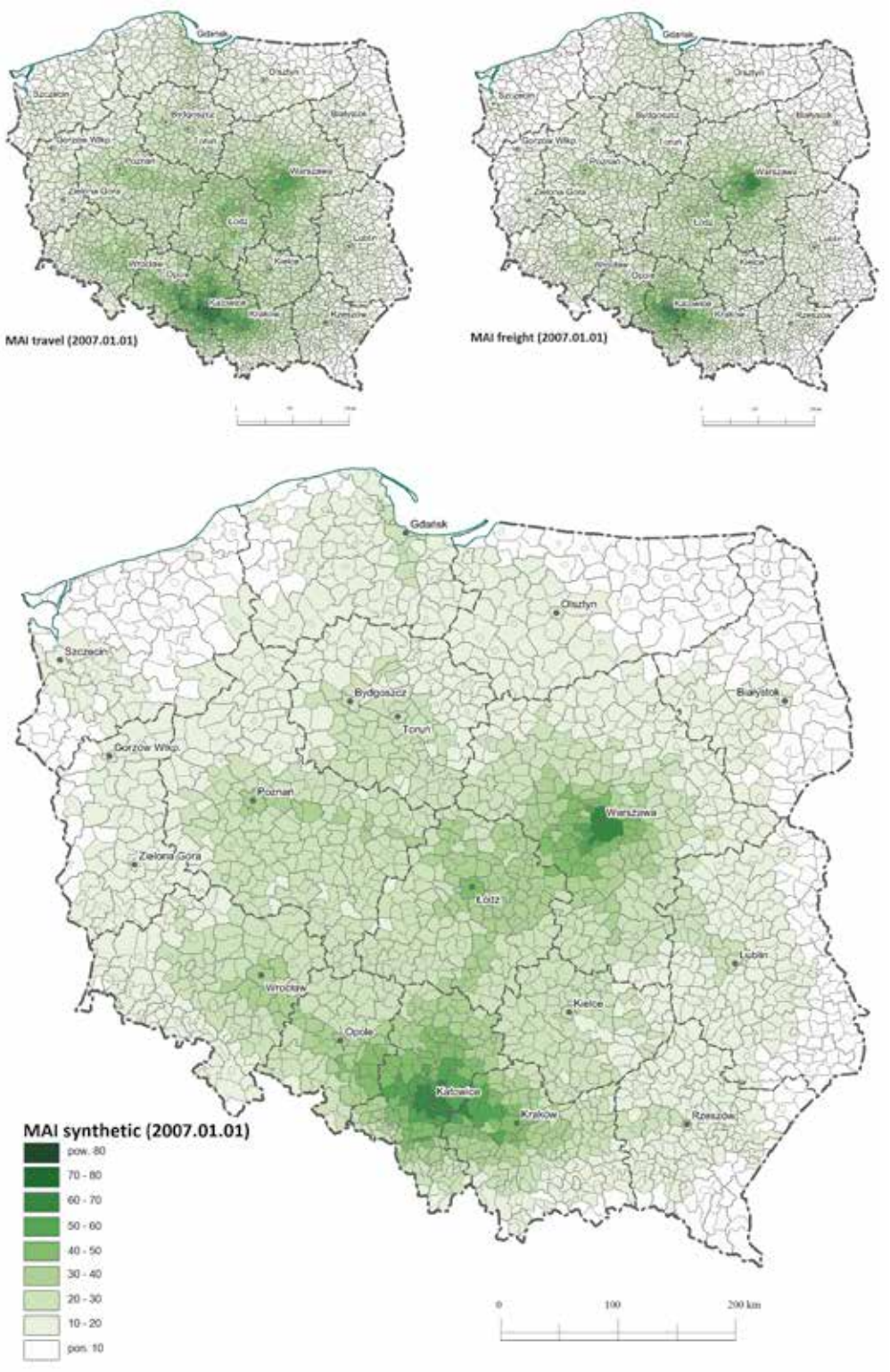

Figure 28. Multimodal Accessibility Indicator MAI (passenger, freight and synthetic) – value as at 2007.01.01

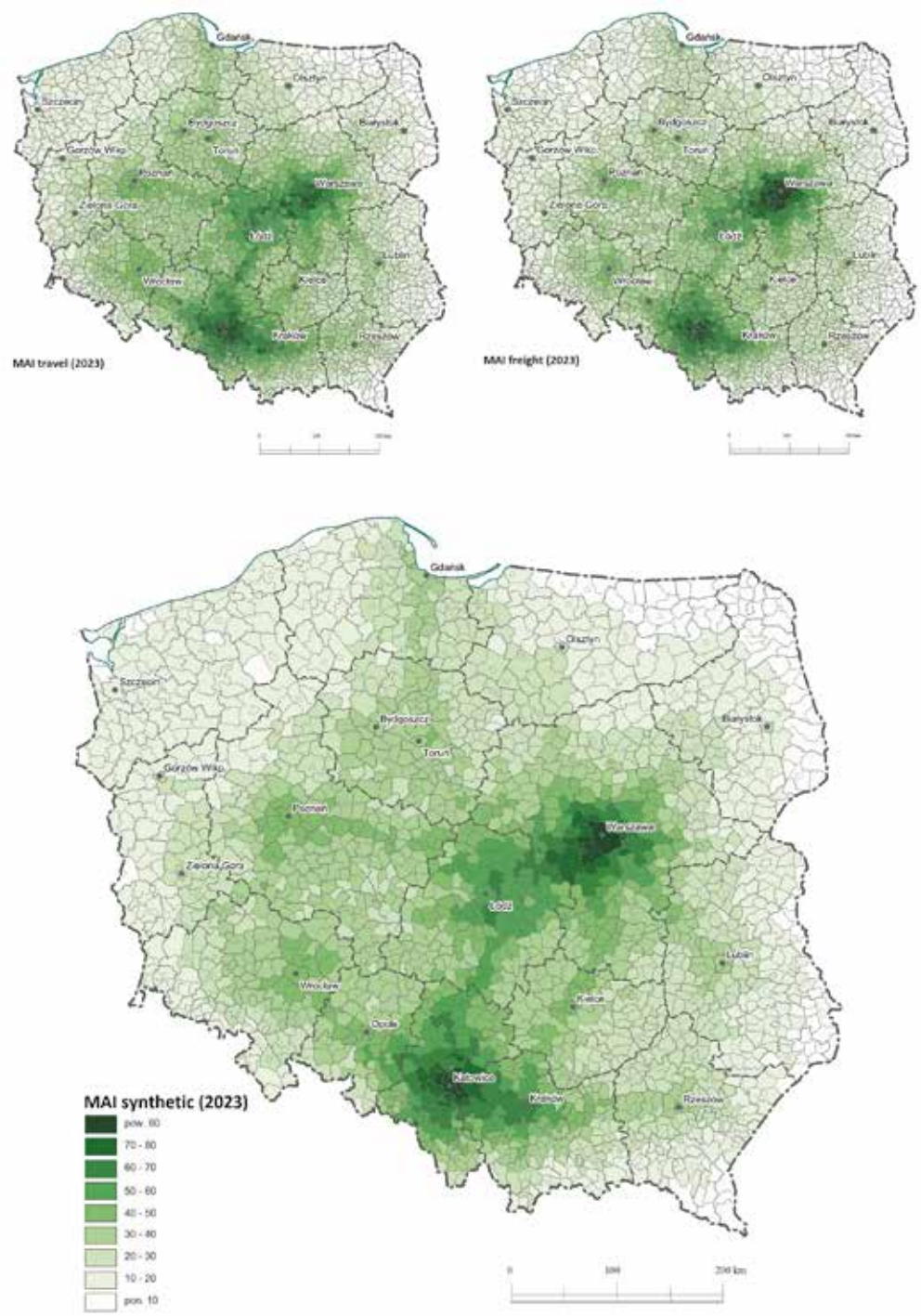

Figure 29. Multimodal Accessibility Indicator MAI (passenger, freight and synthetic) – value as at 2023 (assuming the implementation of investments according to the state of knowledge as at mid-2014)

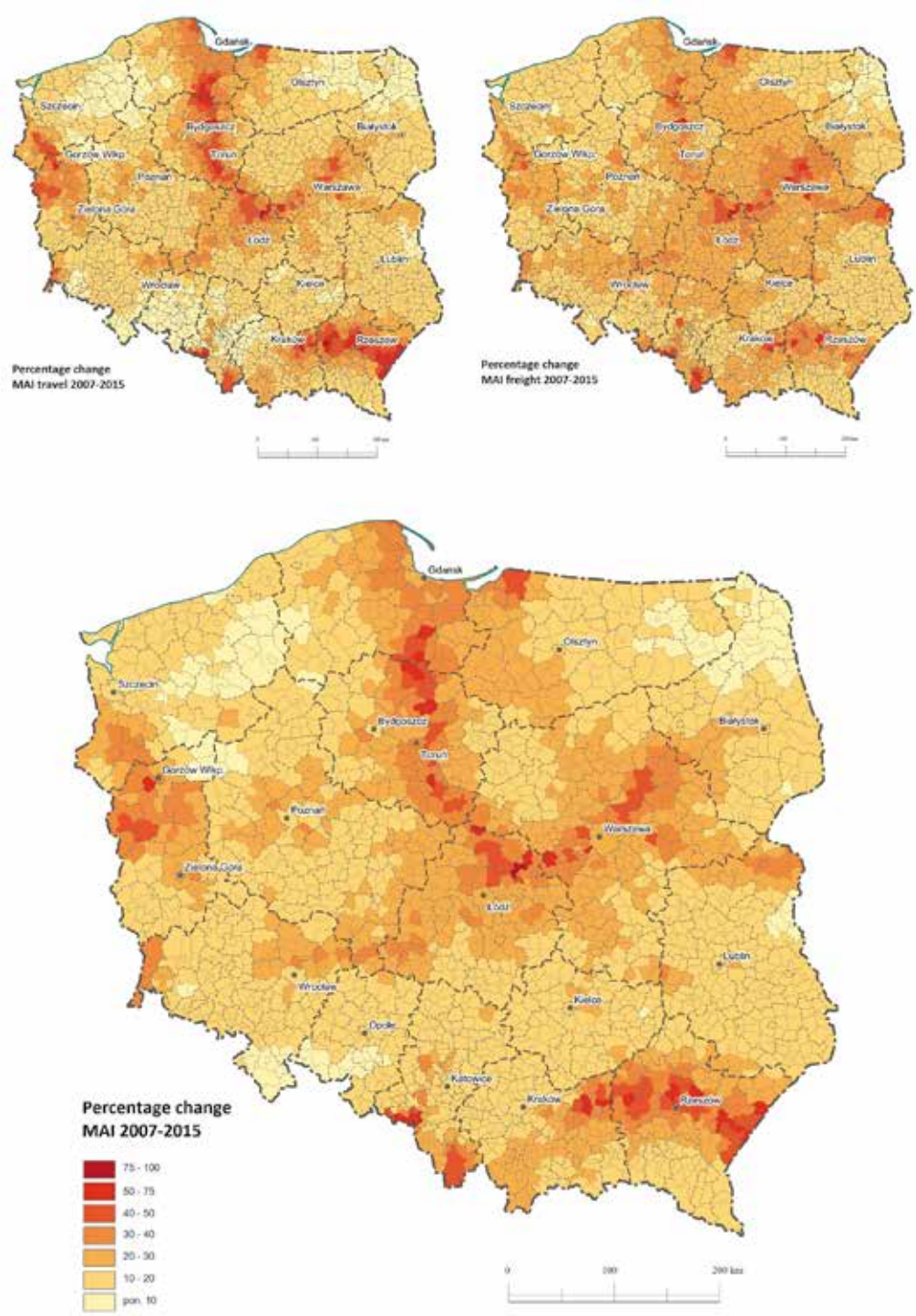

Figure 30. Percentage change in the Multimodal Accessibility Indicator MAI (passenger, freight and synthetic) in 2007-2015

5. Application potential of MAI. Accessibility monitoring (2004-2023)

The accessibility indicator MAI provides many educational opportunities, also as part of a constant monitoring system, which is especially beneficial from the viewpoint of the operation of such bases as STRATEG (system created by GUS for the purposes of programming and monitoring development policies).

As part of continuous monitoring of the accessibility phenomenon, biannual images of changes (basic measurement of accessibility monitoring) were presented both for **accessibility dynamics** (since 2004) and for **changes in spatial differentiation** in the studied period (Potential Accessibility Dispersion index – PAD). Research results were presented in the context of accessibility changes on the voivodeship level in relation to the weighted average of changes for the whole country. Accessibility data at the commune level, aggregated accordingly to the voivodeship and country level, was adopted as the starting point. The analysis was conducted for data as at the end of 2004, 2006, 2008, 2010, 2012, 2015 and 2023. For 2015, investments ending in 2016 but implemented as part of the programming period 2007-2013 were included as well. The choice of those years followed from the following premises. Firstly, the investment intensification processes and, consequently, the acceleration of accessibility changes, were taking place from the very beginning of Poland's entry into the European Union – because of that, 2004 was chosen as the starting year. Secondly, the primary stipulated interval of accessibility analysis should be a two-year period – hence the two-year gaps between individual observations included for 2004-2012. Thirdly, the inability to conduct analysis as at the end of 2016, with the concurrent need to present the most reliable and up-to-date data as at the end of 2015, has resulted in not listing the data as at the end of 2014 in favour of including the calculated 2015 plus variant. Fourthly, the analysis is closed off by 2023 according to a prediction based on lists of investment planned for implementation by the beneficiaries, as well as a prediction of changes to population and the GDP.

Results were shown for every mode in the form of charts illustrating the dynamics of changes in the respective indicators on the voivodeship level. Focus was placed on general conclusions related to accessibility the dynamics at the mode level.

In **road transport** (**synthetic RoAI**), a general increase in accessibility in all the voivodeships is taking place. As a result of intensive investments in motorways and expressways in central Poland, as well as high GDP dynamics and the large population in the Warsaw agglomeration, accessibility improvement is particularly visible in the Masovian and Łódź Voivodeships. Mazovia and Upper Silesia remain the best accessible voivodeships in 2023, whereas the Masovian Voivodeship will

be the "leader" in road accessibility. The following voivodeships are also above the average for Poland in 2023: Łódź, who is "ahead" of Lesser Poland in the ranking. The broadly defined area of best accessibility remains the same, but its centre of gravity moves noticeably towards north. There are however no large changes in the group of least accessible voivodeships (Fig. 31).

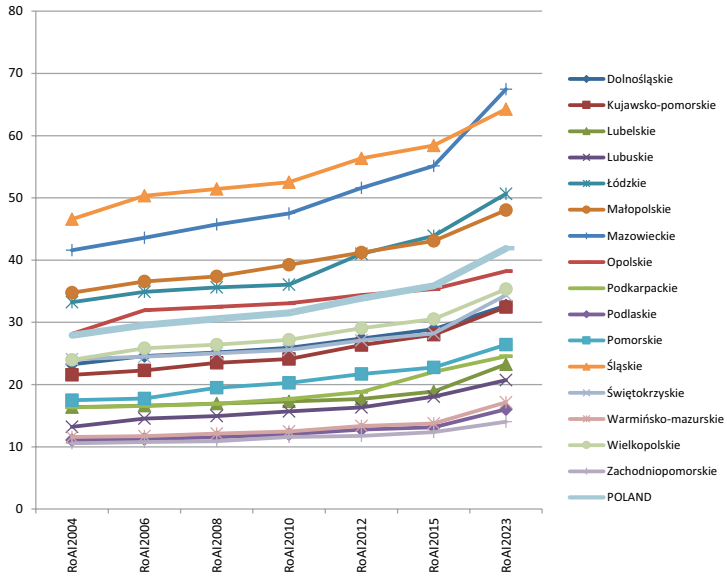

Figure 31. Dynamics of the synthetic RoAI indicator

In **railway transport** (**synthetic RaAI**), the average accessibility in Poland has been increasing thorough the entire researched period, however, in individual voivodeships, the network degradation and closing of railway lines, as well as negative demographic tendencies (population decline in certain areas) resulted in a decrease of railway accessibility. Such a situation occurred, among others, in Upper Silesia during the 2008-2010 period and in the Łódź Voivodeship in 2004-2006. By 2023, the situation will have improved significantly in all voivodeships, though in the Pomeranian and Warmian-Masurian Voivodeship the improvement will be relatively smaller than elsewhere (Fig. 32).

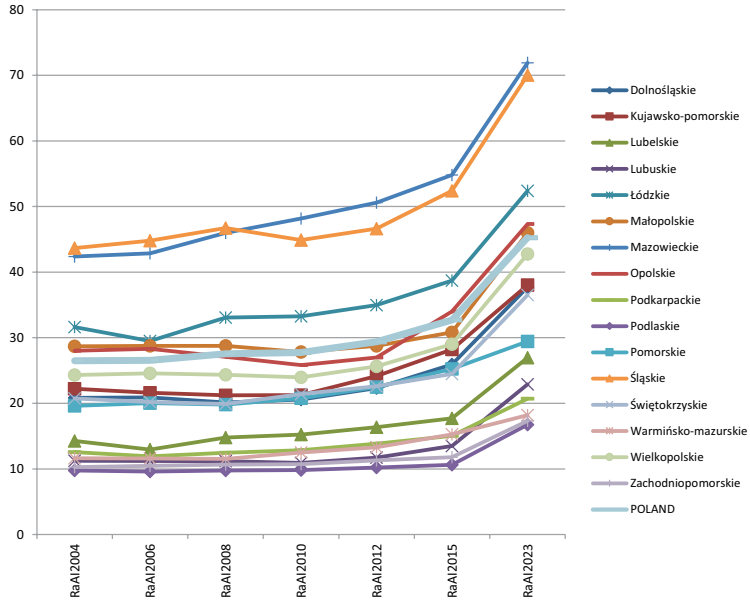

Figure 32. Dynamics of the synthetic RaAI indicator

In **air transport** (AAI), there is a strong dominance of Mazovia as the best accessible region of the country. This dominance grew even more as a result of commissioning the second airport in this region, in Modlin. Second place, as a result of improving road accessibility to airports (primarily to the Warsaw Chopin Airport, through the southern section of the Warsaw express ring road and the A2 motorway) is occupied by the Łódź Voivodeship (mainly thanks to the improvement in the road accessibility to airports in the neighbouring voivodeships) and it is closely followed by the Lesser Poland and Silesian Voivodeships. Other voivodeships remain below the country average for air accessibility. Increase in air accessibility until 2023 will be lower than in 2012-2015, when an unprecedented "flood" of infrastructural investments increasing the capacity of airports occurred (Fig. 33).

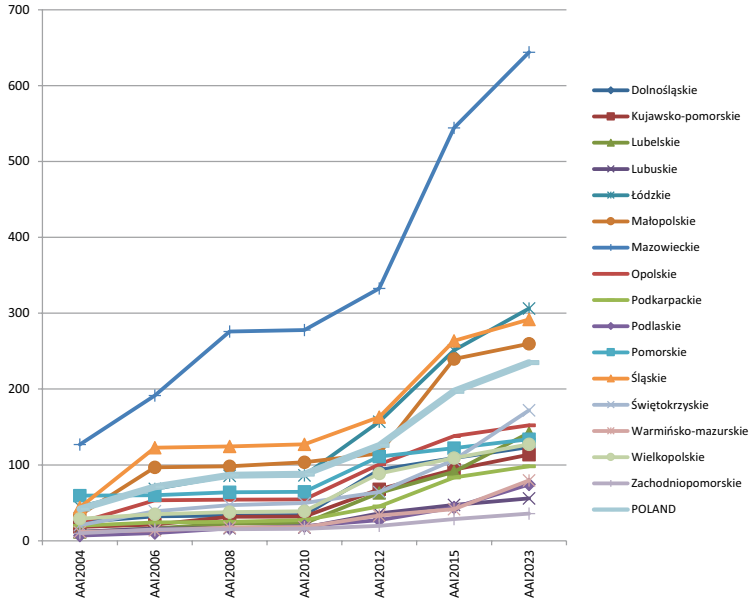

Figure 33. Dynamics of the AAI indicator

In **inland water transport**, the best accessible voivodeships are the four regions located along the Odra Waterway. As a result of investments planned until 2023 and the activation of the water route to Noteć, the accessibility of Kuyavian-Pomeranian, Pomeranian and Greater Poland Voivodeships is significantly increasing. The relatively low position of the Silesian Voivodeships, "connected" to the Odra Waterway thanks to the Gliwice Canal, is surprising. The other voivodeships remain below the country average, and the accessibility of some of them is practically marginal (Fig. 34).

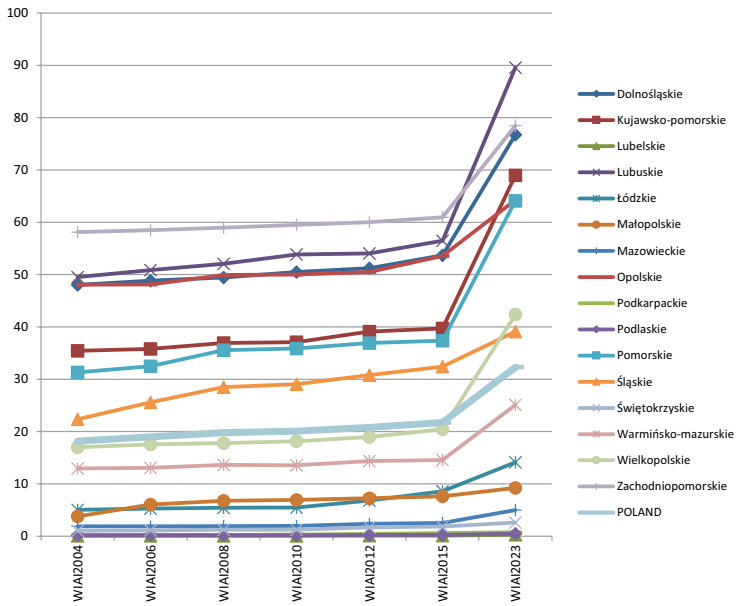

Figure 34. Dynamics of the WIAI indicator

The **synthetic indicator MAI** and its dynamics in individual voivodeships are, to a large extent, a derivative of the formation of the road indicator RoAI. Despite the relatively small differences in biannual intervals for the whole country (e.g. RoAI changes of around 2-5%) from the voivodeship point of view, large investments often results in rapid accessibility changes (e.g. commissioning the first sections of A1 motorway in the Pomeranian Voivodeship or S8 expressway and A2 motorway in the Łódź Voivodeship resulted in a rapid increase in road accessibility in these voivodeships by more than 10%). Furthermore, the analysis of regional differences (further in the chapter) shows how rapidly individual investments may mitigate or further increase regional polarisation. Because of this, the presented research provides arguments for the need of constant biannual monitoring (Fig. 35).

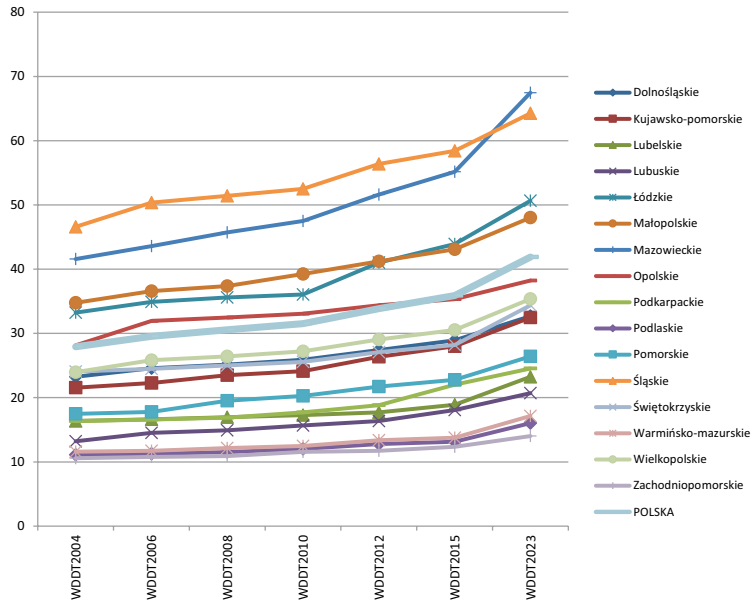

Figure 35. Dynamics of the synthetic MAI indicator

Accessibility differences in 2004-2023. PAD Potential Accessibility Dispersion index. The analysis of the accessibility phenomenon dynamics is complemented by the research on its differences. For this purpose, the PAD (*Potential Accessibility Dispersion*) index was used, which is created through a ratio of the accessibility indicator standard deviation to the average weighted by the population indicator value on the commune level. The higher the indicator value, the higher the accessibility differences and the lower the indicator, the lower the differences. In the dynamic presentation, a decrease of spatial polarisation occurs as a result of the indicator value decreasing in time, while an increase in polarisation – as a result of the indicator increasing. A positive phenomenon, from the point of view of the cohesion policy, is therefore a decrease of the indicator value.

The PAD indicator was calculated separately for each mode and for the synthetic indicator MAI. In the case of the road indicator RoAI, railway indicator RaAI and multimodal indicator MAI, results were presented for passenger transport (Pas), freight transport (Fre) and in synthetic presentation (synth) (Tab. 7).

Table 7. Values of the PAD Potential Accessibility Dispersion index

	2004	2006	2008	2010	2012	2015	2023
RoAITravel	0.376	0.389	0.384	0.383	0.390	0.386	0.384
RoAIFreight	0.397	0.405	0.407	0.407	0.415	0.415	0.421
RoAIsynth	0.384	0.395	0.393	0.392	0.399	0.397	0.399
RaAITravel	0.430	0.438	0.437	0.432	0.426	0.431	0.407
RaAIFreight	0.452	0.454	0.471	0.468	0.472	0.478	0.459
RaAIsynth	0.430	0.436	0.442	0.438	0.436	0.442	0.423
AAI	0.656	0.670	0.716	0.711	0.589	0.632	0.633
WIAI	1.034	1.000	0.983	0.982	0.958	0.945	0.932
MAITravel	0.375	0.388	0.384	0.381	0.387	0.385	0.382
MAIFreight	0.398	0.406	0.410	0.409	0.417	0.418	0.419
MAIsynth	0.384	0.394	0.394	0.392	0.399	0.397	0.397

Regional accessibility differences in road transport. In the case of RoAI (road accessibility), it is clearly visible that a successive deterioration of situation with respect to regional policy occurs in 2004-2012, whereby this deterioration is visible primarily in freight transport. Construction of motorways and expressways results in an increase in traveling speed above all for individual motorised transport. In heavy goods transport, these effects are not so spectacular since heavy goods vehicles cannot move faster than 90 km/h, even on motorways. Thus, there are no polarisation decrease effects visible in heavy goods transport as a result of, for example, the construction of the northern fragment of A1 motorway or S3 expressway towards Szczecin, what occurred in individual motorised transport in 2008-2010. In the 2010-2012 period, further spatial polarisation was taking place, as a result of commissioning sections of motorways located in central Poland (A2 and A1) in 2012. In the following period, i.e. in 2012-2015, the situation improved, mainly due to the construction of a long section of A4 motorway towards the peripherally located South-Eastern Poland, accessibility improved significantly primarily for the Subcarpathian Voivodeship. Also of high importance is the accessibility improvement in the Lower Silesian, Lubusz, Lublin, Podlaskie and Warmian-Masurian Voivodeships as a result of commissioning successive sections of expressways in these peripherally located voivodeships. By 2023, the situation in respect of regional differences in road accessibility should have improved, at least in the case of individual motorised transport. Plans include the execution of, among others, a section of S19 expressway between Lublin and Rzeszów and sections of S61 towards the Polish-Lithuanian border, which will significantly improve the situation of peripheral areas. However, progress in road transport in respect of eliminating interregional differences in accessibility will not be as spectacular as in railway transport, which means that the distance in regional accessibility differences between both transport modees will decrease (Fig. 36).

Regional accessibility differences in railway transport. In general, the railway network is not as dense as the road network and this alone is an important factor contributing to much greater disproportions in railway accessibility (RaAI) than in road accessibility (RoAI). Furthermore, at the time of the access to the European Union, the railway network was heavily degraded. Differences in accessibility between central regions (connected with relatively faster inter-agglomeration lines) and peripheral regions (where railway lines were primarily degraded and of regional importance) were increasing, whereas, which is important, the cause was the increasing accessibility polarisation in freight transport. It may be concluded that the degree of degradation of freight lines located peripherally in relation to the country centre (e.g. the so-called Nadodrzanka) progressed much faster than the degradation of lines connecting the main agglomerations. In passenger transport in 2006-2012, a slow process of decreasing interregional differences took place, as a result of investments improving the accessibility of peripheral areas (e.g. the line towards Siedlce) and, on the other hand, very long-term investments in inter-agglomeration connections (e.g. on the line between Warsaw and Gdańsk). A significant improvement in inter-agglomeration connections in 2012-2015 is clearly visible on the chart (increase in regional differences in this period). By 2023, as a result of investments planned by PKP PLK, interregional disproportions will have decreased significantly, which is related primarily to the planned improvement and reactivation of regional railway lines in peripheral areas, but also an increase in the radius of influence of large cities, e.g. as part of new and modernised railway lines towards Cracow (from the south of Lesser Poland) or Warsaw (from Płock) (Fig. 36).

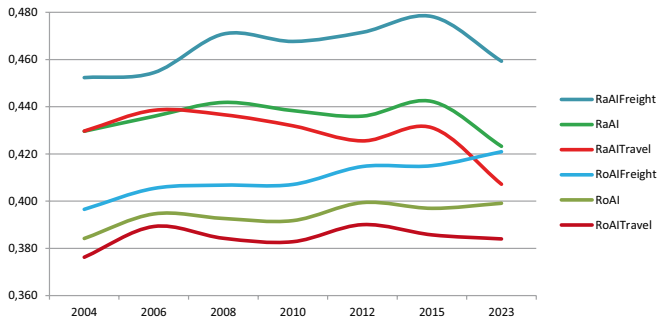

Figure 36. Dynamics of accessibility differences in road and railway transport, divided into passenger and freight transport and a synthetic presentation

Regional accessibility differences in passenger and freight transport. Comparision the results for passenger and freight transport shows that both in road and railway transport, accessibility in freight transport exhibits stronger differences than accessibility in passenger transport. This is related to two issues. First, speeds achieved in heavy goods road transport and heavy goods railway transport are much lower than in the case of individual motorised transport or passenger trains for each mode respectively. This means that the radius of influence of large cities (e.g. cities with large population or areas of high Gross Domestic Product) is much smaller than in passenger transport. This in turn is equals larger differences in accessibility between central and peripheral regions in terms of freight transport. The second issue essential for explaining the reasons for higher accessibility differences in freight transport is the inclusion of GDP as a factor influencing the so-called travel destination attractiveness. In Poland, GDP generated primarily in agglomerations, which determines the higher "mass distribution" differences in space in freight transport

than with the traditional population presentation (passenger transport). This is the second reason for greater accessibility differences in freight transport in comparison to passenger transport. Furthermore, the process of regional divergence (in absolute terms) also takes place takes place, both in the economic and demographic sense, which means increasing differences in the distribution of attractive masses for the benefit of central regions, characterised by high potential (potential increases not only as a result of infrastructural investments, but also as a result of the population growth and high GDP dynamics in agglomerations), and at the cost of peripheral areas, whose low potential grows only as a result of infrastructural investments. In conclusion, in passenger transport, decrease of the polarisation level in road transport is already an observed fact (it takes place in 2015). Distribution of planned investments causes the situation until 2023 to be rather stable. In the case of railways, the change of trend towards a decrease in spatial differences is still before us. Until 2015, the differences were growing. In the 2023 perspective, they are supposed to decrease spectacularly. This will happen only if all the currently planned investments are executed. Possibly omitting certain activities (e.g. the expensive construction of new lines) may cause the decrease in differences to be much less spectacular.

Regional accessibility differences in air and inland water transport. The lower the density of the transport network in the mode in question, the higher the accessibility differences. It should be of no surprise, then, that road transport exhibits the lowest differences, followed by railway transport, while air transport (AAI indicator) and inland water transport (WIAI) exhibit much higher differences. Thanks to the development of regional airports (where particularly large investments took place in 2010-2012) and improving vehicle access to them, a decrease of disproportions in air accessibility between regions occurred. However, large investments in airports in Warsaw and Cracow in 2012-2015 result in a reversal of this positive in terms of cohesion trend. Until 2023, the lack of larger investments results in maintaining relatively high regional accessibility differences in air transport (Fig. 37).

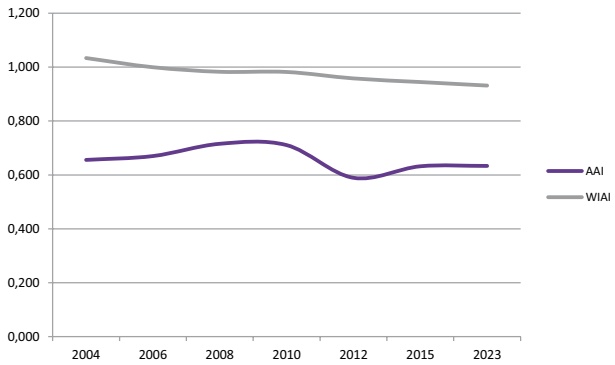

Figure 37. Dynamics of accessibility differences in air and inland water transport

On the other hand, situation improves in inland water transport as a result of the planned activation of the Noteć water route and also the improvement in the heavy goods transport accessibility to river ports. However, only a very small section of the country may realistically benefit from services provided by this transport mode.

Regional accessibility differences – the MAI indicator. The synthetic indicator MAI behaves similarly to the RoAI indicator. Since 2012 a slow decrease in interregional difference is taking place, with the exception, however, of the freight indicator, where, above all as a result of further GDP concentration in agglomerations, a slight increase in differences is taking place) (Fig. 38).

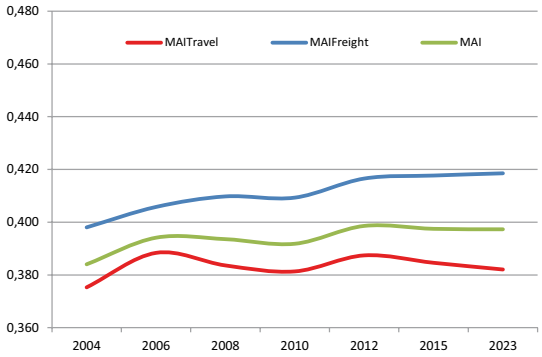

Figure 38. Dynamics of accessibility differences – MAI indicator

6. Conclusions and recommendations from the study

Conclusions and recommendations from the accessibility study were divided into those concerning:

- diagnosis of the spatial distribution of accessibility in Poland,
- dynamics of changes within the context of the spatial distribution of accessibility,
- results of individual operational programmes,
- isochronous analysis,
- air and inland water transport,
- monitoring system (including dynamic analysis of dispersion indicator differences).

Conclusions and recommendations concerning the spatial distribution of accessibility in Poland

The study confirmed spatial distributions of national potential road and railway accessibility known from earlier analyses. Throughout the entire research period, **two poles: Warsaw-Łódź and Cracow-Upper Silesia** were the areas of best accessibility, from which propagated belts of better accessibility, related to the land transport infrastructure being erected or modernised. In both modes, areas of the best accessibility were Mazovia (primarily areas around Warsaw) and Upper Silesia, followed by areas in the Lesser Poland, Opolskie, Masovian and Łódź Voivodeships. In freight transport, the dominance of the Silesian and Masovian Voivodeships was clearer. In railway transport, the main lines were the most visible, surrounded by belts of better accessibility.

Areas of better accessibility in land transport (and, at the same time, in the multimodal presentation) are related to a polygon which may be identified **with the network metropolis stipulated in the KPZK 2030 document.** For passenger transport, this polygon is based on Wrocław, Poznań, Gdańsk, Warsaw, Lublin, Rzeszów, Cracow and Katowice. In freight transport, its reach is more spatially limited, and is based on Wrocław, Poznań, Bydgoszcz, Warsaw, Cracow and Katowice.

The area with noticeably higher accessibility indicator levels was rather spatially limited in 2007. This situation stemmed from the balanced and still low development level of road and railway

infrastructure. **Differences in accessibility were determined then by the distribution of demographic and economic potentials** and the distance of entities from the main centres of these potentials. **Infrastructure improvement results in the area of high accessibility kind of "spilling" from the most accessible poles to other regions**. Concentration of GDP in the area of the two main (Warsaw-Łódź and Katowice-Cracow) and three supplementary (Wrocław, Poznań, Gdańsk) poles of high accessibility causes **the greatest accessibility improvement to stem from investments connecting the rest of the country with these exact centres**. By the same token, some of new or modernised road or railway routes do not contribute to the expansion of good accessibility areas in freight transport.

In the light of the adopted research methodology, accessibility improvement in road and railway transport in the future will be additionally dependent on the predicted GDP growth in the individual regions. Improvement in passenger traffic will depend to a higher degree on the interventions undertaken, though in some areas depopulation movements (peripheral regions), migration flow (largest centres) or intense suburbanisation processes (agglomerations) will also have an impact.

Analysis of **international accessibility** (RoAIa) confirms the special position of some areas in Western and South-Western Poland, where the accessibility at the European level is very high, while national accessibility is relatively much weaker. Investments scheduled for implementation by 2023 will not change this situation significantly. Northern and Eastern Poland will be the primary beneficiaries of better accessibility at the European level.

In conclusion, **accessibility is improving as a result of many factors**. Due to the population concentration and GDP growth processes, areas located in the vicinity of the main development poles (metropolises) sometimes also improve their accessibility, independently of undertaking any new investments. The attractiveness of such centres increases. By the same token, the MAI indicator level has increased in their neighbouring areas (or even in more remote areas with better transport connections).

Conclusions and recommendations concerning the dynamics of changes and spatial distribution

For changes in the 2007-2015 period, road investments were the most significant and they had a direct impact also on the improvement of air, water inland and, locally, even railway (travel to the closest stations) accessibility indexes. The improvement related to investments in the 2007-2015 period was rapid in the **Warsaw-Łódź pole**. Broader areas of good accessibility took shape. Belts of better accessibility along the A2 and A4 motorways were more clearly visible. What had the greatest impact on changes to the spatial image was the A1 motorway (from Stryków to Gdańsk), causing the accessibility of the Tricity to improve by leaps and bounds. First signs of integration between the two poles could be observed as well. In the voivodeship-based presentation, attention is drawn to the position of the Masovian and Silesian Voivodeships as national accessibility leaders. **Changes in the 2007-2015 period were changes benefiting the Masovian Voivodeship** (both in passenger and freight transport). The Łódź Voivodeship position was similarly reinforced in relation to the Lesser Poland Voivodeship.

By contrast, **railway investments** in the **programming period 2007-2013** are clearly concentrated in three areas of the country. Road accessibility increases significantly within two triangles, i.e. between Warsaw, Gdynia and Bydgoszcz and between Łódź, Katowice and Zielona Góra. A large accessibility increase is also noticeable east of Warsaw, in the direction of Terespol. In **railway** transport, due to generally lower accessibility, the majority of activities is justified by and significantly improves the situation with respect to reduction in peripherality. The scale of planned activities in railway transport is so large that even a partial implementation of investment plans will result in very high changes to accessibility.

In general, the **key role of some investments for the entire transport system** of the country and for the accessibility level of expansive territories was confirmed. This applies first to some sections of motorways, but also to modernised railway lines, where speed was significantly increased or which had a special location in the network. It is a premise for concentrating funds on the most important investment activities (after prior detailed *ex ante* analysis in respect of accessibility improvement).

Infrastructure improvement resulted in the better accessibility area "spilling" from the most accessible poles to other regions. **Starting investments from the largest nodes concentrating demographic and economic potential instantly affected the entire area serviced by the road** (example: S8 towards Białystok). Starting it from the side of the smaller regional centre (example: S17) causes the activity to have a primarily local significance and the spatial reach of the accessibility improvement effect to be smaller and shifted towards even more peripheral areas. This allows for formulating recommendations concerning the role played by the sequence of implementing the individual section of linear investments.

Investments (both road and railway investments) located on the peripheries cause the greatest percentage improvement of accessibility, but with a limited territorial reach. This is caused by often overlapping border and low base effects. At the same time, investments in central locations provide a larger network effect. Thus, the thesis concerning the key importance of central investments for the improvement of Eastern Poland accessibility was confirmed.

Accessibility may be **noticeably improved** along the entire length of some routes **even through investments are undertaken only on some sections** (in particular in system bottlenecks, e.g. construction of ring ways). This may incline towards commencing certain road investment in the current financial perspective, even if the budget capabilities do not allow for implementing entire routes. On the other hand, staging of activities should take into account the effectiveness of already completed sections, giving priority to investments providing the most spatially expansive accessibility improvement.

An important issue is the **location of nodes on motorways and expressways.** It is the determinant for access to these routes from secondary roads and, by the same token, a decisive factor for the spatial reach of the positive net effect. These results are a premise for carrying out variant *ex ante* accessibility analyses already at the stage of initial preparation for the new investment.

The spatial effect of individual large linear investments is not proportional to their length. It depends on the **location relative to the primary centres of the settlement system, as well as industry regions and centres** (freight transport). It is also conditioned by earlier infrastructural investing. At the local scale, specific solutions, such as, among others, the location of nodes on motorways, also have an impact on this effect. Furthermore, successive road and railway investments change the layout of the **shortest travel paths** between cities and regions. This has clear consequences in future timetables and should be taken into account when making decisions during the programming period 2014-2020.

In conclusion, Poland is slowly entering the development phase where some regions become **saturated with modern transport infrastructure** (**road** and air infrastructure in particular). This applies primarily to the western and southern parts of the country. In these areas, successive road investments give noticeably lesser effects in respect of accessibility improvement, although links between the existing higher class roads closing the network completely may become key after 2023. Due to the above factors, the distribution of planned accessibility changes becomes a better premise for making further investment decisions than it was in the previous financial perspective (the generally weak accessibility in the entire country justified any activities).

Conclusions and recommendations concerning individual operational programmes (OPIaE, OP EP, ROPs)

In the programming period 2007-2013, amongst all the road investments supported with EU funds, the largest was the **net effect of the Operational Programme Infrastructure and Environment**. From the relative point of view, on the country level, it reached almost 9%. Analogous effects for the Programme Development of Eastern Poland reached only 0.14%, while for all the Regional Operational Programmes together it was only 0.5%. In railway transport, the analogous OPIaE effect reached 4.85%, while the effect of sixteen ROPs – 1.09%.

The scale of **effectiveness** for road **investments** implemented under **16 Regional Operational Programmes** was also diverse. The 1% level was exceeded in the Lesser Poland Voivodeship, while values over 0.7% were recorded in the Świętokrzyskie Voivodeship. At the same time, in some regions (Lubusz, Lublin, Pomeranian and West Pomeranian Voivodeships), the effect was insignificant (lower than 0.25%). In the case of the Operational Programme Development of Eastern Poland, effects exceeding 1% (or close to that value) were recorded only in the Świętokrzyskie and Lublin Voivodeships. In railway transport, the largest beneficiaries were: the Lubusz (6.92% accessibility increase) and Subcarpathian (4.94% increase) Voivodeships. From the absolute point of view, the Łódź Voivodeship benefited the most (primarily due to the improvement of accessibility to Łódź from the direction of Łowicz).

Transport policies of some voivodships (implemented as part of ROPs) turned out to be more effective (in terms of accessibility increase) than others. This particularly applies to the Warmian-Masurian, Kuyavian-Pomeranian, Świętokrzyskie, Lesser Poland and Greater Poland Voivodeships. In these voivodships, the MAI indicator increase as a result of ROPs was clearly higher and often also more spatially cohesive. At the same time, in some regions, the effect of road investments as part of ROPs is practically invisible. At the local scale, effects of investments under

ROPs were clearer in the peripheral regions of the country, which stems from the fact that the modernised roads are more often the primary access route there, i.e. they provide the quickest access to attractive destinations in the whole country.

Investments implemented as part of OP IE and ROPs are complementary to a high degree from the spatial point of view and complement the image of improvement to railway accessibility in Poland. An exception to this are the Podlaskie and Lesser Poland Voivodeships, which are characterised by the lowest percentage accessibility change as a result of railway investments co-financed from European Union funds. In general, the effect of investments under ROPs is more visible in the peripheral areas of the country. It is there where the "low base" effect applies and voivodeship roads more often fulfil the role of a link with large cities in Poland. This situation can be observed along the country borders, especially along the Czech Republic, Slovakian and Lithuanian borders and the border with then Kaliningrad Oblast.

Investments on **voivodeship roads** (primarily ROPs) provide a more territorially expansive effect of improving accessibility in peripheral areas, including the borderlands. Their role is also significant wherever they improve access to already existing higher level infrastructure (motorways and expressways, but also modernised railway lines for higher speeds).

In conclusion, the **role of coordinating interventions on the central government (OPIaE) and regional government (ROPs, OPDoEP) levels** in achieving territorially cohesive accessibility improvement effects was confirmed. This coordination should also have a multimodal nature (complementarity of large railway investments with regional road investments).

Conclusions and recommendations stemming from isochronous analysis

The actual **cumulative accessibility** to voivodeship cities as centres of workplace and public service concentration is dependant not only on developing the transport infrastructure, but also on the occurring demographic changes (including unregistered ones) and on institutional factors (service regionalisation).

The progressing concentration of population in large metropolises causes locating road investments on routes leading to them to be more effective from the point of view of observing improvements in cumulative accessibility indicators. On the other hand, there are areas within the territory of Poland that, by 2023, will become severed from regional centres despite the planned wide-scale road investments. Some of them may improve their situation only if the roads listed in KPZK 2030 are constructed. Development of the road network until 2023 will be beneficial for expanding certain **labour markets** and areas of influence in the service sphere. Cities benefitting from the investments will be Warsaw, but also Wrocław, Poznań, Bydgoszcz and, in Eastern Poland, most of all Rzeszów.

Road investments, through expanding the **range of influence of voivodeship cities**, will temporarily compensate for the quantitative losses on the labour market (in the vicinity of some cities) related to the demographic crisis. In the following years, the scale of road investments will pass the point where strong **network effects** will be revealed, expressed, among others, in the

individual cities entering the range of influence of neighbouring voivodeship centres. This will be favourable for synergic effects and an increase in economic effectiveness and competitiveness.

It seems advisable to **route expressways** in such a manner that they also fulfil intraregional functions. This applies particularly to connections between sub-regional level cities and voivodeship centres. In this context, it is possible to indicate a few clearly deprived cities, which, also in 2023, will remain outside of the modern road network and, at the same time, outside of the areas of good accessibility to the native capitals. These include: Płock, Kalisz, Jelenia Góra, Wałbrzych, Nowy Sącz and Ostrołęka. Areas of low accessibility were identified as well, located on the peripheries of the largest voivodships, including in borderlands, for which travel time to voivodeship capitals will be relatively long. These are in particular Middle Pomerania, Suwałki Lake District and part of the Masurian Lake District, Zamojszczyzna with Roztocze, Bieszczady and Kurpie. Servicing them in the future poses additional challenges related to depopulation and deterioration of the age structure.

In conclusions, isochronous analysis has shown that preparing a list of road investment priorities should in the future take into account the **demographic factor** and changes occurring in the population distribution to a greater degree, as factors changing (modifying) the significance of individual investments. In agglomeration systems, it is necessary to coordinate transport and urban policy and planning, i.e. particularly in respect of spatial development plans on the voivodeship and commune levels.

Conclusions and recommendations concerning air and inland water transport

The capacity of the largest airports in the country was at least two times, and in certain cases a few times lower in 2007 than by the end of the programming period 2007-2013. Vehicle access to airports was also hindered by the lack of motorways on most access routes. **The spatial distribution of air accessibility in Poland is, also in 2015, determined by the location of two airports in Mazovia,** i.e. the capacity of Warsaw Okęcie airport (and, to a lesser degree, the new Warsaw Modlin aiport), as well as by the road system providing access to the most important airports. This means that the best accessibility is in the vicinity of the capital metropolis and in the A2 (from Poznań to Warsaw) and A4 (from Wrocław to Cracow) road belts, with a "peak" of accessibility between Katowice and Cracow.

By percentage, Eastern Poland benefited the most from air investments (over threefold AAI indicator increase), including in particular the Lublin and Podlaskie Voivodeships, primarily as a result of opening new airports in Lublin and Modlin.

In **inland water transport,** the change in the situation in 2007-2013 stems primarily from the improvement in the road infrastructure condition and, though to a much lesser degree, from the spot investments on the Odra Waterway. Investments scheduled in the programming period 2014-2020 should significantly improve the accessibility in this transport mode.

In conclusion, the conducted research confirms the thesis that **improvement of accessibility in air transport may be achieved both by erecting or modernising airport infrastructure (new**

structures, capacity increase) and by developing land transport. It is a premise for a critical reflection on the purposefulness of undertaking certain new investments in the form of erecting airports. Further development of **airports** (aside of investments planned in certain airports, e.g. in Warsaw or Modlin) is hard to justify in light of the high capacity parameters stemming from investments implemented in the programming period 2007-2014, and also due to the improvement in access to the existing airports, both via road and railway transport. In the case of **inland water transport**, the planned investments may significantly increase the accessibility of this transport mode. Attention should however also be paid to the economic effectiveness of investments implemented outside of the Odra Waterway.

Conclusions and recommendations from the monitoring system (including the dynamic analysis of regional diversity)

In this period (2007-2015) we are observing a **slight increase in the degree of polarisation in both discussed transport modees**. The level and variability of dispersion indicators prove that polarisation is (in all the time periods) noticeably higher in railway transport than in road transport (among others, the result of non-uniform railway network coverage of the country and decapitalisation of network in certain regions). In the case of road transport, the regional differences decrease by 2010 due to, among others, commissioning the northern section of A1 motorway and S3 expressway. On the other hand, in 2010-2012, polarisation increases rapidly as a result of intensive investment activities (among others, commissioning the centrally located section of the A2 motorway between Łódź and Warsaw). Later, as successive investments are completed, the dispersion level starts to decrease. In railway transport, the changes are less unambiguous. After the period of decreasing polarisation (2008-2012), it currently started to increase again. This may be interpreted as the **effect of delays in fundamental inter-agglomeration railway investments in relation to road investments**.

From the point of view of the cohesion policy, **investment plans until 2023** should be judged favourably. In all the analysed transport modees the situation improves in this respect, although, to date, the transport policy has not yet stopped the negative trend of depopulation in peripheral areas at the cost of population increase in agglomeration, as well as concentration of GDP in central regions.

From the point of view of increase in accessibility and decrease in interregional differences, **investments resulting in increasing the influence radius of large cities and agglomerations**, also those located in peripheral areas, e.g. Białystok, Lublin or Rzeszów, are more important than investments in peripheral areas. In this context, investments in exit roads from cities, implemented, e.g. with the use of the Operational Programme Development of Eastern Poland 2007-2013 / Eastern Poland 2014-2020 should be judged favourably. The complementarity of investments undertaken on the central and voivodeship levels (e.g. linking regional roads to the motorway and express routes network) is important as well.

In time (probably primarily after 2023, i.e. after having completed the largest investments), the accessibility level will again be increasingly affected by the demographic (mainly migration movements of the population) and macroeconomic situation (economic activity concentration

and de-concentration processes). This is significant for the future transport policy, which has to increasingly take into account conditions of this type, and thus has to be integrated with the government economic and social policy more than today.

In conclusion, **in road transport we are dealing with the initial territorial cohesion growth phase, while in railway transport it remains in the sphere of targets for the next financial perspective (2014-2020).** Polarisation in respect of accessibility should not, however, be translated directly into social and economic differences. Improvement in the indicator values in central and southern regions of the country remains proportional to the concentration of population and the concentration of production and export potential. Furthermore, polarisation of transport accessibility is, as has been shown, a temporary phenomenon. In this context, it is particularly important to continue the commenced investment process. In general, until 2023, a decrease in regional polarisation is visible in railway transport, but railway accessibility will still be more spatially "polarised" in 2023 than road accessibility.

7. Strategic conclusions concerning the use of MAI

The consecutive steps of work on preparing the MAI indicator are a good example of designing modern application tools on the foundation of multiannual international and national scientific research. Earlier evaluation practice was dominated by indicators related to the effective use of funds and simple measures based on the physical scale of the undertaken investments. On the other hand, a full comprehensive evaluation of the impact of transport investments on development is difficult and requires long time series. Furthermore, conclusions stemming from such analyses are often contradictory (Crescenzi and Rodriguez-Pose 2012). The possible positive impact of investments on development may be highly spatially diversified (Wegener et al. 2005), depending on the initial situation (the base effect; *Investing in Europe's Future...* 2010), but also on the geographic scale the research is conducted in. In these conditions, developing the potential accessibility methodology allowed for creating a set of objective measures filling the gap between simple quantitative indicators and complicated models with ambiguous results. Measures of accessibility changes are essentially indicators of creating new development opportunities resulting from better connection of entities with external potentials. These opportunities may be used or not. However, they can be evaluated objectively even before implementing the investment, which, in the case of actual impact on economic activation, remains very difficult.

It may be assumed that the role of the MAI indicator as a tool to evaluate the purposefulness and effects of transport investments will grow together with the development of infrastructure. In the initial phase of development programmes, all the projects were easy to justify, which stemmed from many years of neglect in the transport sector. Most of the investments also brought relatively a high increase in accessibility indicators (particularly from the relative point of view – the low base effect). At the current stage, systems are being gradually completed (the road network in particular). The accessibility of many cities and regions has improved. By the same token, the effectiveness of completing further segments is becoming more and more varied. Some of them are essential, particularly from the point of view of particular centres, the impact of others may turn out to be relatively small when compared to the investment costs. At the same time, it should be noted that the pool of funds for transport projects will decrease after 2020 (due to the uncertain future of the EU cohesion policy, but also due to Polish regions growing richer and achieving the GDP threshold levels entitling to use structural funds). The choice of investments for implementation will have to be much more precise (preceded by a reliable *ex-ante* evaluation, preferably in the variant presentation). The MAI indicator provides very high capabilities for such an evaluation.

The accessibility indicator turned out to be a very good tool for parallel and complementary work in various geographic scales. The ability to conduct analyses in European, national and regional "closure" enables the indirect identification of the most significant beneficiaries of individual projects. Thus, this tool may be used to verify investment plans sometimes undertaken for political reasons.

The research confirmed that transport investments are not the only factor deciding about the accessibility level. The predicted changes to the attractiveness of goals (unit masses) and also, indirectly, changes to the mobility of people and companies (shape of the distance resistance function) are very significant. In the long-term presentation, this allows for using the indicator for purposes other than evaluating transport investments. Territorial evaluation of such processes as depopulation of peripheral areas and concentration of people in metropolises or regionally non-uniform GDP growth is possible.

The long period of analyses conducted according to unchanging methodology makes Poland a unique "case study" of changes to accessibility in times of rapid infrastructure development. This causes the completed research to gain significant scientific value (both in the cognitive and methodological sense; Rosik et al. 2015). This provides a chance to use the Polish example in international discourse, including in particular on the European Union level, concerning such issues as the future of the cohesion policy, validity of the concentration of funds, general evaluation policy and the European transport policy.

Research using the accessibility indicator may also be important for evaluating policy in respect of modal changes. If one of the transport policy targets is a modal shift towards more environmentally friendly types of transport, then the undertaken investments (especially railway investments) have to be evaluated through changes of the accessibility indicator (modal, but also multimodal). Modernisation of lines that do not improve accessibility most likely will not bring the expected effects (or such an effect will be attainable only via the financial approach – subsidies and/or toll roads). Results of the analyses may, in this context, be a part of discussion about the need to create high speed rail (as an alternative to modernising existing lines) and about the construction of rapid urban rail (as an alternative to expanding the tramway network). The air accessibility indicator may also be helpful for making decisions related to erecting new airports (including the possible Central Airport and regional facilities in a few voivodeships pursuing this).

In conclusion, evolution of the accessibility measurement concept as part of the Multimodal Accessibility Indicator, occurring as a result of the expansion of knowledge in the transport area and in order to meet the challenges of the monitoring system for the purposes of the programme perspective 2014-2020, was translated into the opportunity to create a globally unique accessibility monitoring system. Because of its detailed nature, it is the **only system operating in the European Union that comprehensively evaluates the effects of all large transport investments within the member state and provides *ex post and ex ante evaluation capabilities*** for any temporal range (e.g. as part of programming periods). Thus, the MAI indicator provides **massive evaluation capabilities in respect of the assessment of the effects of individual infrastructural investments and programming periods**.

Using the MAI indicator is purposeful in the context of continuous monitoring of the accessibility changes phenomenon. It is recommended to implement **basic accessibility monitoring** (calculation of indicators in modal and synthetic presentation), optimally in a **two-year cycle** (each two years starting with 2004, which has already begun as part of the project: *Opracowanie instrukcji monitorowania zmian dostępności transportowej na potrzeby ewaluacji and sprawozdawczości z realizacji dokumentów programowych dot. polityki spójności perspektywy 2014-2020 oraz dokumentów strategicznych (krajowych and regionalnych)*) (*Developing an instruction for monitoring changes in transport accessibility for the purposes of evaluation and reporting on the implementation of programme documents concerning the cohesion perspective 2014-2020 and strategic documents (national and regional)*). Basic accessibility monitoring should consist of taking into account investments implemented in all the modes of transport in subsequent years, updating demographic (number of people) and economic (GDP) data each time, calculating the MAI indicator set (all the modes and spatial levels) based on the presented methodology and **feeding the STRATEG database** (system created by GUS for the purposes of programming and monitoring the development policy) consistently. For the purposes of regular monitoring, in order to collect information about infrastructural investments, there is a need for constant contact with the beneficiaries, i.e. the General Director for National Roads and Motorways GDDKiA, Polish State Railway PKP, Marshall Offices, Presidents of cities with county rights in respect of data on infrastructural investments being implemented or planned (among others, the name, nature, implementation period, duration, chainage, cost, source of financing, degree of co-financing), and also technical speed limits on the railway network (PKP PLK S.A.). Data concerning population and GDP changes is publicly available and does not require additional activities for collecting it.

Should additional needs arise, aside of the biannual system, conducting additional annual measurements is also possible, if such a demand arises on the part of the Ministries or GUS. They would be justified by the appearance additional demand on the part of the transport and spatial policy (e.g. development of new strategic documents or evaluation requirements on the part of the European Union), or as a result of an emergent demand for new indicators (potential inclusion of accessibility measures in macroeconomic models of economic development).

The conducted research also leads to the conclusion that the MAI methodology should be further perfected, which could allow its new uses with a broad practical component, including:

- expanding work to the European scale (in the first stage for the V4 states area), including the geopolitical factor (variable delay parameters on state borders; expansion of the method proposed by Rosik (2012));

- expanding the cross-border presentation (according to the methodology proposed earlier by Więckowski et al. (2014)), especially on the Poland-Germany, Poland-Czech Republic and Poland-Slovakia borders;

- conducting research on the possible restrictions to accessibility as a result of environmental dangers, disasters and social and political events (floods, destruction of bridges, roadblocks, etc.),

– possibly enabling analyses on the local and also interurban levels, also taking into account pedestrian and bicycle traffic, as well as intermodal solutions (including *park and ride* parking lots).

In the cognitive sense, it may be advisable to further broaden the time horizon (historical presentation), which would allow for a more accurate determination of the impact of infrastructure development (measured with accessibility improvement) on social and economic development. A large part of past research in this respect consisted of attempts to directly compare the scale of investments (e.g. kilometres of constructed motorways) with changes to economic indicators (most often GDP). As it has already been mentioned, they did not provide unambiguous answers. Crescenzi and Rodriguez-Pose (2012) also note that negative results obtained in econometrical models may be the result of politically conditioned choice of projects for implementation. Long-term research on changes in potential accessibility would eliminate this problem (wrong decisions by politicians would not improve accessibility). Participation in the discourse on this subject may be helpful in, among others, negotiating the possible, even if small, financial support for Polish infrastructure in the next EU financial perspective.

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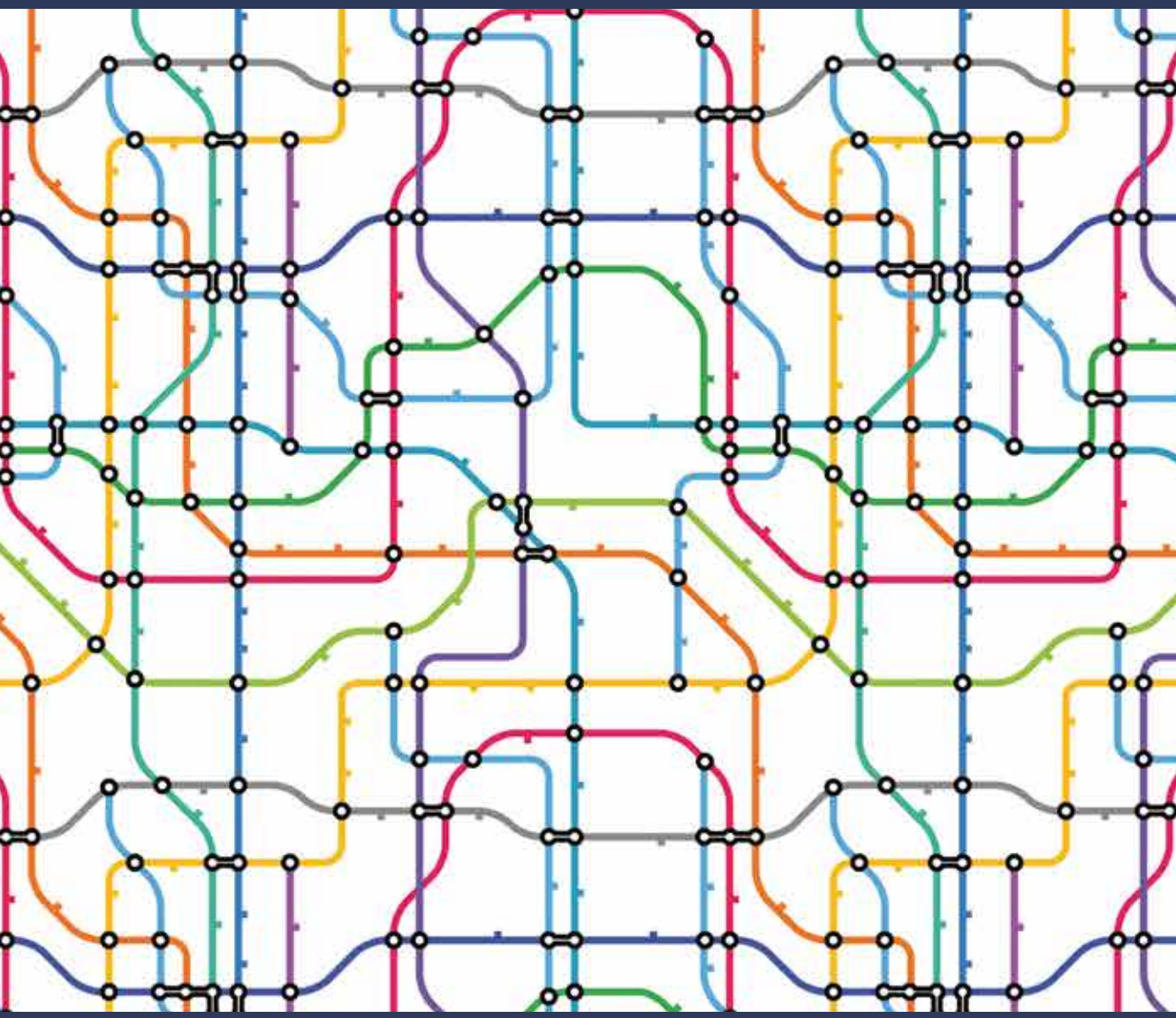

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