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EVALUATION OF ACCESSIBILITY CHANGES IN POLAND USING THE MAI INDICATOR

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Introduction

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', 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 was 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 including the projects pursued 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. This publication results from research conducted under the project titled "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 (Multimodal Accessibility Indicator) 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).

Evolution of work on the MAI indicator

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: "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 (Komornicki et al. 2010b). In 2010, MAI was used for the first time in a broader evaluation context in the IGSO PAS report: "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. 2010a). In turn, in the another research project (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.

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 of territorial cohesion of communes in the national and international scales in 1995-2030" (Rosik et al. 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 carried out by Komornicki et al. (2013). 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 described project.

Methodological assumptions of the MAI indicator

Accessibility examination methods. The project uses first of all potential accessibility (potential model), based on which the Multimodal Accessibility Indicator MAI was built (objectives I, II, IV, V), and temporal accessibility (isochronic analysis; objectives III and V). Potential accessibility is the most frequently encountered approach in studying transport accessibility (Hansen 1959; Geurs & Ritsema van Eck 2001; Wegener et al. 2005; 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. 2010a; Rosik et al. 2012; Komornicki et al. 2013; 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.

$$A_i = \sum_j f_1(M_j) f_2(c_{ij}) \qquad (1)$$

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;* in study making use of MAI, the measure of distance decay is the travel/carriage time; the analysis made use of the exponential function $f(c_{ij}) = \exp(-\hat{a}t_{ij})$, where the appropriate parameter was indicated as $\hat{a} = 0{,}023105$ (see Spiekermann et al. 2013; Stępniak et al. 2013; Stępniak & Rosik 2013; Rosik & Stępniak 2015).

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. 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.

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 (Komornicki et al. 2008; Rosik & Śleszyński 2009; Śleszyński 2009, 2015; Rosik et al. 2011; Rosik 2012). 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.). 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. 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.

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. 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. 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).

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 (Tab. 1).

Table 1. 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.

Time scope. 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 (for methodology, see Stępniak & Rosik 2016) in the studied period (Potential Accessibility Dispersion index – PAD). 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. 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.

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 (Fig. 1).

Strategic conclusions concerning the use of MAI

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).

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. 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 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.

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.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

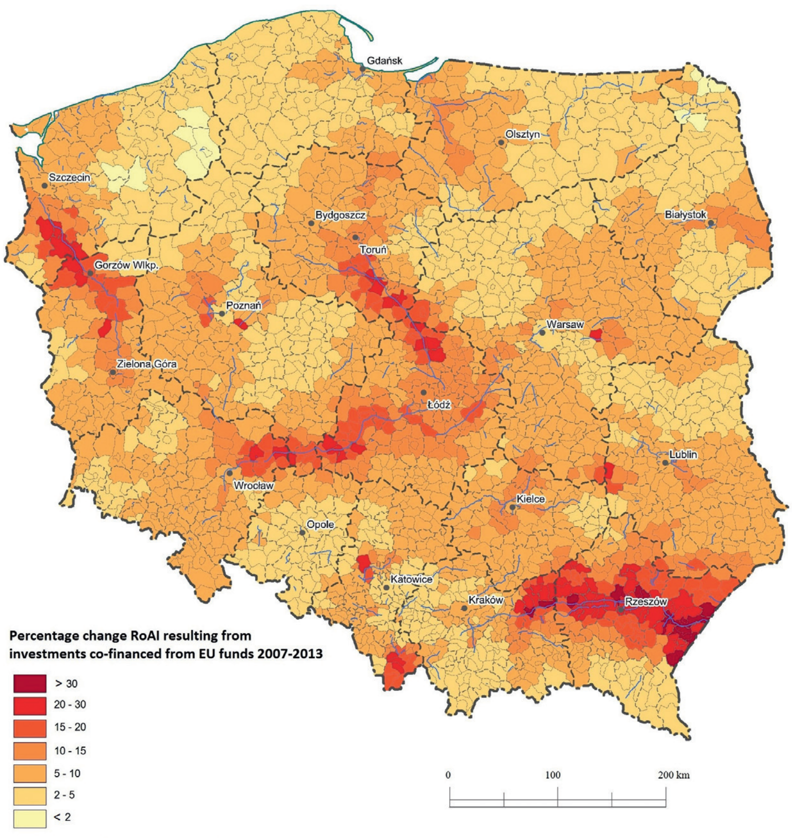

Figure 1. Percentage change in the synthetic Road Accessibility Indicator RoAI as a result of all investments co-financed from the EU funds in the programming period 2007-2013

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