Michał KOWALSKI*, Szymon WIŚNIEWSKI*

TRANSPORT ACCESSIBILITY AND MOBILITY: A FORECAST OF CHANGES IN THE FACE OF PLANNED DEVELOPMENT OF THE NETWORK OF EXPRESSWAYS AND MOTORWAYS IN POLAND

Abstract. The article presents a forecast of changes in the level of transport accessibility and mobility in Poland as a result of the anticipated development of the network of expressways and motorways. The progress which has been made in this respect in the last few years in Poland is unquestionable and unrepeatable by any other European country. Will the subsequent investment plans concerning the road network of the highest parameters offer equally impressive results as far as the increase in Poland's territorial cohesion is concerned? The aim of this article is to establish in what way the planned infrastructure investments will affect the changes in transport accessibility and mobility as well as whether they will result in the changes in traffic flows directed to Warsaw and other regional centres. To achieve this, an analysis of the present and target states of the road network in Poland was conducted from the perspective of the changes in accessibility, anticipated traffic flows, and mobility. For this purpose, the authors used the analyses of isochrone and accumulative accessibility in ArcMap environment and the research into traffic flows and their changes in the Visum software. The conducted research showed that the planned transport network might result in induced traffic through an increase in accessibility (the central variant) with the assumption that an increase in mobility would be vented in the real face of the phenomenon of motility. The fact of opening new road sections of expressways will contribute to substantial changes in the directions of traffic flows only to a slight extent, and the only transformations concern regions with already developed fast car transport infrastructures whose functionality is limited due to the lack of cohesion in the subsequent course or lack of a developed network of expressways and motorways.

Key words: accessibility, mobility, road infrastructure, Poland.

* Michał KOWALSKI, Szymon WIŚNIEWSKI, University of Lodz, Faculty of Geographical Sciences, Institute of the Built Environment and Spatial Policy, ul. Kopcińskiego 31, 90-142 Łódź, Poland; e-mails: michal.kowalski@geo.uni.lodz.pl, szymon.wisniewski@geo.uni.lodz.pl

1. INTRODUCTION

A study of accessibility and motility is one of the most frequently accounted factors that enable the assessment of transport investments. It renders it possible to perform an ex-post and ex-ante evaluation of the significance of the implementation of any given investment. For that purpose, it is the most common practice to utilise research into cumulative accessibility (e.g. Komornicki and Śleszyński, 2009; Wiśniewski, 2016), measured by means of the potential method (e.g. Komornicki *et al.*, 2013a) and the mobility method (e.g. Bocarejo and Oviedo, 2012; Vigar, 2013). In the light of the above, it seems imperative to begin with a presentation of what accessibility and mobility truly are.

So far there has not been, and most likely there will never be, a single and universal definition of "transport accessibility" that would be binding for all researchers (Rosik, 2012). As indicated by Gould (1969), accessibility is "one of those common terms that everyone uses until faced with the problem of defining and measuring it." Others stated that accessibility is an "inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example time and/or distance)" (Ingram, 1971). Other researchers have also developed their own definitions, among others: Vickerman (1974), Komornicki and his team (2010), Hansen (1959) and Martellato with his team (1998), Handy and Niemeier (1997) Bruinsma and Rietveld (1998), Black and Conroy (1977), Cauvin (2005), Biosca *et al.* (2013), Kozina (2010), Karou and Hull (2014), Gutierrez *et al.* (2010), Geurs and van Wee (2004), Makkonen *et al.* (2013).

Regardless of the applied definition, the majority of authors indicated the presence of certain constituents, elements or components, which are necessary for the appropriate comprehension of the issue and which constitute integral ingredients of transport accessibility (Dalvi and Martin, 1976). Thus, one can distinguish four basic components of accessibility (Geurs and van Wee, 2004), two of which play a decisive role in this study. Those are the transport component, represented by the road network – the entirety of the principles that condition movement within a network, and the component of land use, which indicates the manner in which a scrutinised land is utilised. The consideration of those two components is one of the most significant assets of transport accessibility since – due to this very feature – it offers feedback between the policies of transportation and spatial management.

The concept of mobility in geographical literature refers to a wide spectrum of phenomena, from the large-scale movement of people, goods, capital, and information to local processes related to everyday mobility and travelling (Hannam *et al.*, 2006). In order to demonstrate the research presented within this article, it is necessary to narrow down the meaning of mobility. All the aforementioned flows ought to be characterised in three basic dimensions: time-related, spatial, and motivation-dependent. While the first two appear to be – due to their rather measurable

nature – quite obvious (objective), the motivation (the destination of the journey understood as: what for?, for what purpose?) represents a more complex issue and is crucial when research questions are posed about the characteristics and relations of travel, since it is virtually impossible to present the phenomenon of mobility and to draw cause and effect conclusions without considering the motivation that lies at the foundation of this mobility. Even if one were able to present all the travel-related phenomena in a specified territory and in a stipulated time, it could lead to blurring of information, which would de facto render it impossible to conduct any sector analyses. Therefore, attempts have been made in source literature to offer generalisations that would enable a more contrasted presentation of mobility-related phenomena.

The application of reductionism within the motivation-related dimension can be found, for instance, in the work by Modenez and Cabré (1998), who coined the terms "usual mobility", "daily mobility", "occasional mobility," and "residential mobility." Then, Kaufmann (2002) organised this approach by referring motivations to the other two remaining characteristics of mobility – time and space. As far as time is concerned, he isolated "short duration" and "long duration" mobility, and divided space into two types of areas: internal to the living area, and near the outside of the living area. In consequence, he presented four major forms of spatial mobility: "daily mobility", which is short-term and limited to the living area, "travel" (short-term movement outside the living area), "residential mobility" (moving home), which belongs to long-term travelling within the living area, and "migration" – i.e. long-term travel outside the living area.

One final remark needs to be made, following the explanation of all the aforementioned terms and concepts. Namely, the said issues related to mobility and accessibility ought not to be equated. Hanson and Giuliano (2004) wrote that accessibility expresses a spatial relation between selected places, while mobility refers to moving within that space. In conclusion, it could be stated, in accordance with Taylor (1999), that mobility is actual moving, and accessibility only describes the potential possibility of such moving. At the same time, however, one should bear in mind that Kaufmann (2002) introduced a peculiar dual voice into the concept of mobility, by stating that, within its framework, there is actual mobility and potential mobility (motility), which ought to be understood as the possibility of any given individual to be mobile (Kaufmann, 2002). This possibility can be satisfied, e.g. by the development of motoring, the expansion of the transport system, and by appropriate planning strategies aimed at decreasing the dispersion of built-up areas (Komornicki, 2011). In this matter, it seems that spatial accessibility is, to a certain extent, a measure of potential mobility. In the presented studies, mobility was demonstrated as motility, i.e. potential mobility.

As mentioned above, the methods of researching accessibility and motility can be applied in the analyses preceding the plans for the expansion of road infrastructure. Nevertheless, one must also bear in mind that apart from such analyses, the process of making a planning decision also involves other elements, such as

social and economic factors (e.g. demand for transport of people and goods), and factors that refer to a wider spectrum of phenomena, i.e. the implementation of goals within the strategy of transport policy, local development, environmental protection (reduction of external environmental effects), as well as, and in numerous countries primarily, implementational feasibility perceived from a technical, technological, and financial point of view (Rosik and Opałka, 2011).

For making ex-ante analyses of transport investments it is fundamental to precede a decision-making process with studies that allow one to simulate the effects of combined investments. This is of crucial importance since, when compared to single case studies, it makes it possible to determine mutual relations between investments, i.e. the influence that the implementation of some investments has on the fulfilment of other (Wolański, 2010).

Therefore, in a situation when there is a limited budget for the implementation of investments, the creation of a mechanism that enables one to select road investments which are the most effective and not necessarily the easiest to implement should lead to the selection of projects which guarantee shortened travel time, the largest number of beneficiaries (both in terms of transportation of people and goods), the improvement of safety, and the possibility for an increase in economic efficiency (Rosik and Opałka, 2011).

The main purpose of this article is to determine how scheduled infrastructural investments may influence the changes in transport accessibility and motility, and whether they will make it possible to notice the changes in the directions of traffic flows into Warsaw and other regional centres. In order to fulfil the purpose, the analysis of the current and planned sizes of the road network in Poland was conducted in respect to the changes in accessibility, predicted traffic flows, and motility.

The work has been divided into three parts, preceded by this foreword and ended with a discussion and conclusions. The first part is a review of source material and the research methods applied in the study. The second contains a short description of the research area. The third was divided into 3 sections, each of which shows the results in three variants: central, interregional, and regional.

2. SOURCE MATERIAL AND RESEARCH METHODS

2.1. Data sources

In the research, the most up-to-date data was used, for instance, from the Database of Topographic Objects – DTO (Baza Danych Obiektów Topograficznych), obtained from the Head Office of Geodesy and Cartography (Główny Urząd Geo-

dezji i Kartografii) in Warsaw, which is the national system of gathering and providing topographic data. Out of the extensive range of the DTO data, information on the course and features (category, class, surface material, number of carriage ways and lanes) of the road infrastructure was derived. Next, some of these features were applied for the purposes of the research on traffic flows in the VISUM software.

The information on mandatory speed limits for individual sections of the road network was derived from the resources of the General Director for National Roads and Motorways – GDNRM (Generalna Dyrekcja Dróg Krajowych i Autostrad), Voivodeship Road Authorities – VRAs (Zarządy Dróg Wojewódzkich) and the databases provided by OpenStreetMap (OSM), which is a social project that allows people to use and edit data on the basis of the Creative Commons license (Haklay, 2010). The algorithm for utilising the data from the aforementioned sources was as follows. Firstly, in accordance with the GDNRM documentation, speed limits were attributed to individual road sections (motorways, expressways, national roads, and some regional roads). Next, the missing sections of the network of regional roads were assigned speed limits concordant with the VRAs' documentation. The remaining sections of the road network (district, local, access roads, and other) were attributed with speed limits, in accordance with the data within the OSM. It must be stated here, however, that the OSM database provides no information on the maximum permitted speed limits for every section of the road network. For those sections for which none of the sources above specified a speed limit, the values applied were those accordant with the Polish Traffic Law Act (1997 Journal of Laws No. 98, Item 602, as amended). It should also be added that while assigning speed limits to individual road sections, the regulation limiting the speed limit within built-up areas was observed.

The information on the scheduled expansion of the transport infrastructure in Poland was derived from the Regulation of the Council of Ministers of 19 May 2016 (Item 784), which changed the regulation on the network of motor and expressways, which is a currently binding normative act stipulating the targeted network of those roads.

As far as the research on motility is concerned, the analysis also encompassed the data on the deployment of all settlement units in Poland with the corresponding numbers of residents (in accordance with the data of the Ministry of Internal Affairs and Administration, the Central Statistical Office, and Town and Community Councils). For each settlement unit, which, according to the data provided by the aforementioned institutions, has at least one resident (73,651 units), a central point was generated and assigned with the number of residents within any given unit. Moreover, data on the deployment and number of economic entities was derived from the resources of the Local Data Bank – LDB (Bank Danych Lokalnych) within the Central Statistical Office. And since the LDB aggregates such data up to the level of a commune (gmina), for each commune in Poland

(with an additional division into rural areas and cities in rural, and urban communes) a central point was generated and assigned with a corresponding number of economic entities. Population as well as the number of business entities were not forecasted. Since it is not possible to determine the moment when road investments will be completed, it is not possible to make a forecast of those variables. All analyses were based on current data.

2.2. Methods dedicated to accessibility research

The measurement of travel time in personal transport is a complex task, since this parameter is determined by a number of factors, such as weather conditions, unexpected road incidents (e.g. collisions), and individual driving styles, and it also varies on a daily, weekly, and annual basis. The research variant of analysing the travel time of personal road transport presented in this article takes into account only one determinant that conditions vehicle speed, i.e. the speed limits imposed by the Traffic Law Act (1997 Journal of Laws No. 98, Item 602, as amended). Thus, the net travel time was stipulated, taking into consideration neither breaks caused by road conditions, nor time taken to rest or refuel. It was assumed that traffic flows at its maximum allowable speed and along the routes that guarantee the shortest possible travel time. Therefore, sections of toll motorways were also considered. While determining accessibility, the shortest route (timewise) was always searched, which did not always coincide with the shortest physical distance.

Transport accessibility can be researched by means of numerous methods. Some authors listed as many as over a dozen of these (Bruinsma and Rietveld, 1998; Spiekermann *et al.,* 2015; Neutens, 2015; van Wee, 2016). The majority of works on the issue, however, are dominated by a certain consensus regarding the most important approaches (Baradaran and Ramjerdi, 2001; Geurs and van Wee, 2004; Geurs and Ritsema van Eck, 2001; Spiekermann and Neubauer, 2002; Salas-Olmedo *et al.,* 2015; Rosik *et al.,* 2015; Żakowska and Puławska, 2015; Ford *et al.,* 2015; Wang *et al.,* 2015; van Wee, 2016; Rode *et al.,* 2017), which include, for instance: infrastructure-based accessibility, distance-based accessibility, cumulative accessibility, potential accessibility, and person-based accessibility (Geurs and van Wee, 2004). Considering the purpose of the study, which is presented in the article, the approaches based on time accessibility are particularly valuable.

In this study, two of these approaches were applied. The analysis based on the measurement of distance was introduced, where "distance" should be understood as a time distance (travel/transport time) between a journey's starting point and its destination or a set of destinations, and as their cumulative accessibility. This method is also known as isochronic accessibility, in which accessibility is measured through estimating a set of destinations available in a specified period of time.

In subject literature, accessibility measured by means of isochrones is sometimes alternatively described as daily accessibility (Śleszyński, 2004, 2007; Śleszyński and Komornicki, 2009). For that reason, in some reviews of methods, accessibility measured by the distance to a set of destinations is placed in the same class as accessibility measured by the means of isochrones. In studies on accessibility, the methods most often find common ground in the form of time accessibility, when time is selected as an element of the function of spatial resistance. The travel time between two points in the Cartesian geographic space is conditioned by a large number of factors that stem from the features of the space itself, the means of transport, and the user of the transport network. It is imperative here to apply numerous simplifications, the most important of which is people's desire to minimise the travel time between the starting point and the destination. It is, after all, one of the most fundamental principles of economic efficiency of social and economic systems. Broadly speaking, the representation of time-related issues on maps dates to the origins of astronomic cartography (Komornicki *et al.,* 2009).

Generally speaking, when accessibility is measured by means of isochrones, the maximum time and cost (budget for the journey) is assumed. Next, the number of destinations available within a specified period of time, or at a specified cost, is calculated (Spiekermann and Neubauer, 2002). Other examples of research on daily accessibility are: Törnquist (1970), Schürmann *et al.* (1997), Spiekermann and Wegener (1996), Vickerman *et al.* (1999), Fransen *et al.* (2015), Widener *et al.* (2015), and Boisjoly and Geneidy (2016).

2.3. Methods dedicated to mobility research

In order to determine potential mobility, methods that enabled an appropriate spatial aggregation of data had to be applied. To determine the number of residents within the specified travel times, it was assumed that all residents dwelled in the central point of any given settlement unit. For this purpose, a central point for each settlement unit was generated and related to the total number of residents of any given unit. Transport analyses based on the central points (representatives of individual communication regions) obviously entail certain problems. That is probably particularly evident in the case of time availability research. This approach does not consider the actual development of the area and the centre of the area understood in terms of function. Nevertheless, they are often used in research (e.g. Rosik and Kowalczyk, 2016) due to the pace of analysis and the ease of interpretation of the results. An alternative to this approach may be the designation of refactory points at the border of a given communication area. This allows one to avoid generalizations regarding the time of travel in a city, which usually suffers from congestion and other factors limiting the freedom of movement of vehicles. Of course, it is debatable how much a city's administrative boundary determines

the occurrence of such problems. In order to illustrate the deployment of economic entities (due to the statistical confidentiality provided by the Central Statistical Office with accuracy to the basic territorial unit – the commune), a centroid was generated for each of the 2,478 communes (with some additional central points for rural and urban areas within urban-rural communes) and information on economic activity in the areas was attributed to each such centroid. In the course of the research procedure, those central points were totalled in individual isochrones. Both in the case of demographic data and the data related to business entities, an assumption was made that their number and deployment will be invariable until the expansion of the road network characterised by the highest parameters reaches the state described in the said regulation.

2.4. Research procedure

The study began with a construction of two sets of network data based on linear layers that presented the distributions of roads in Poland. The first layer showed the current state of affairs, while the second the planned network of roads. During the creation of the sets of network data, the time required to travel through individual sections of the network (calculated earlier on the basis of segment length and the maximum allowable speed within the section – the use of maximum speeds is a simplification that we decided to use to accelerate the study and increase the ease of interpretation of the results) was taken as a default attribute. Next, on the basis of those sets of network data, work in the New Service Area within Network Analyst tool was commenced. In the central variant, Warsaw (its centroid) was nominated the starting point for constructing travel isochrones. The analysis was performed twice – on the current road network and on its planned variant. The New Service Area tool was also applied in the regional perspective, with centroids of voivodeship capitals as points into which isochrones were drawn. Then, within the areas limited by individual isolines of identical travel times for the existing road network and the planned scenario, settlement units and numbers of residents and economic entities were counted so that, in the following step, they could undergo a comparative analysis. For the purpose of interregional analyses, the New OD Cost Matrix tool was utilised, with centroids of voivodeship capitals (18 out of 18) as starting points and destinations. Next, travel times recorded in the existing and planned road networks were compared. By means of various colours of ribands between individual cities, bilateral time differences were presented, and a cake diagram map was used to illustrate the aggregated changes in travel time for the whole collection of the 18 voivodeship centres.

As far as the analyses of traffic flows and their changes accompanying the expansion of the transport network in Poland are concerned, the VISUM software was used (Rosik and Kowalczyk, 2015, Rosik *et al.,* 2016). As in the case of the

research on accessibility, that stage of the analysis also included a simulation of the network load for the central (Warsaw) and regional (voivodeship capitals) variant of the existing and planned infrastructure of the road network in Poland. For the purposes of that analysis, it was assumed that residents of individual settlement units in Poland (transport regions) travel to Warsaw or to voivodeship capitals within the borders of which they live. In order to determine the number of vehicles that will set out on the road, travelling from each of the transport regions, the level of motoring in Poland calculated at the district level was applied (at this level, the Central Statistical Office provides information on the number of vehicles per 1,000 residents). The applied research tool for the analyses of traffic flows also required data on the course of individual segments of the road network (linear layer), their capacities (vehicles per hour), structures (number of carriageways and lanes), lengths, maximum allowable speeds, and the speeds of free-flow traffic. The data on road capacity and the free-flow speed were derived from the literature on road traffic engineering (Brzeziński and Waltz, 1998; Gaca *et al.,* 2008). The two aforementioned variables were assigned to various combinations of structure and class of road network segment. That was how capacity was assigned to each segment of the road network in its existing and planned forms. In macro traffic models, it was assumed that a traffic flow is uniform and can be determined by three variables: intensity, density, and the average speed of traffic. In the case of uniform traffic, those parameters are linked by a relation called the equation of vehicle flow. One of the results of the application of the aforementioned assumption was the creation of the so-called Volume Delay Functions. Those functions take the form of relatively simple equations that enable the evaluation of average speeds on congested sections of roads by means of information on their capacity. In order to estimate the travel time of any given section for individual transport vehicles, the section delay functions are applied, which use such variables as: traffic density, road capacity, and free-flow speed. One of the simplest functions of this type is a function formulated by Overgaard, which is a combination of the functions offered by Soltman and Smock (Birr *et al.,* 2013):

$$\mathrm{T} = T_0 \cdot \alpha^{\left(\frac{N}{C_p}\right)^{\beta}} \tag{1}$$

where:
   T – travel time in a segment,
   T_0 – travel time in a segment at free-flow speed,
   N – traffic density in a segment,
   C_p – critical density (maximum capacity),
   α, β – model parameters.

$$T = T_0 + \left(1 + \alpha \cdot \left(\frac{N}{C_p} \right)^{\beta} \right) + \gamma \cdot V \tag{2}$$

where:

    T – travel time in a segment,
    T_0 – travel time in a segment at free-flow speed,
    N – traffic density in a segment,
    C_p – critical density (maximum capacity),
    V – maximum allowable speed in a segment,
    α, β, γ – model parameters.

In the VISUM software, this model takes the following form:

$$t_{cur} = t_0 \cdot (1 + a \cdot sat^b) \tag{3}$$

where:

$$sat = \frac{Q}{c \cdot Q_{max}} \tag{4}$$

    Q – traffic density [veh/h]
    t_{cur} – travel time in a segment loaded by traffic density Q
    t_0 – travel time in a segment at free-flow traffic conditions
    Q_{max} – capacity [veh/h]
    a, b, c – parameters.

The parameters of the BPR function were taken from the research conducted by Rosik and Kowalczyk (2015, p. 187). From the same study, the space delay function was borrowed, which took the form of an exponential function with the following parameter $\beta = 0.011552$, which returns a 50% decrease in attractiveness of the trip destination after an hour, 75% after two hours, and 90% at nearly 3 hours and 20 minutes of driving. The motivations to take a journey, as applied by Rosik and Kowalczyk (2015), include business trips, visits paid to relatives and friends, and tourism. In two cases, the spatial distribution of vehicle traffic density for these reasons clearly corresponds to the distributions practised in this study – business trips correspond to the variant of travelling to Warsaw, and visits paid to friends and family correspond to trips taken to voivodeship capitals. In the case of the former, the applied model is suited at the level $R^2 = 0.41$, and the model assumptions for the latter correspond to the reality at the level $R^2 = 0.64$.

The research procedure presented above returned vehicle traffic density for individual segments of the road network in its existing state and its planned variant. Next, symbolisation was performed, in the form of continuous thematic symbol map, whose thickness corresponded to the vehicle traffic density in individual segments.

3. RESEARCH AREA

Poland's accession to the EU created new opportunities of funding infrastructural investments, including in transport. That led to the Big Push, which contributed to changes in the transport landscape in Poland thanks to the processes of rebuilding and developing the road network on a local, regional, and national scales (cf. Stępniak and Rosik, 2013; Rosik *et al.* 2015; Wiśniewski, 2016). And it was in the east of Poland that those investments had the greatest impact on the increase of potential accessibility (Komornicki *et al.*, 2013). During that time, the foundations of the express and motorway network were laid (Fig. 1). At present, the road system of Poland is based on routes that run latitudinally (motorways A2 and A4), longitudinally (motorway A1 and expressway S3), and across the country (from south-west to north-east, expressway S8). The aforementioned network is complemented by more fragmentary sections of expressways and a relatively dense system of national and regional roads. Some parts of the said roads are also fragments of European routes.

As a result of those transformations, there occurred a sudden improvement in transport accessibility of Polish regions and cities. A particularly important achievement of that time was an increase in transport accessibility related to personal transportation streaming to the capital city of Warsaw (Rosik *et al.*, 2015).
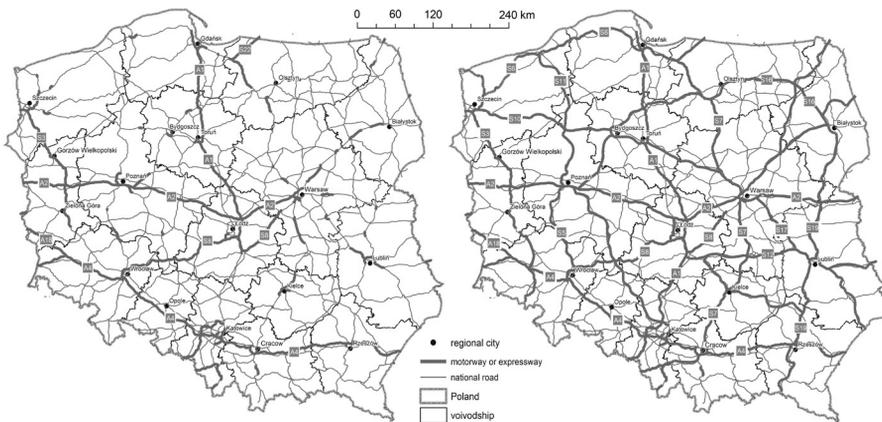

Fig. 1. Polish network of national roads, expressways and motorways in 2017 (left) and its target layout (right)

Source: own work on the basis of the Regulation of the Prime Minister altering the regulation on the network motorways and expressways.

The spatial distribution of accessibility to Warsaw is radial in its nature, which is typical for European capitals located inland. The shape of isochrones,

to a large extent, stems from the radial layout of roads leading to the capital city. The longest radii correspond with the stretch of the S8 expressway and the A2 motorway. Their "jagged" nature stems from the deployment of interchanges and exits within those roads as well as the stretches of roads that join the network of expressways and motorways (Fig. 2). The influence of the fragmentary sections of the S7 and S10 expressways is also noticeable; despite their lack of continuity, they still contribute to the growth of time accessibility. Another factor that influences the accessibility to Warsaw is the more distant A1 motorway, which – through the hub with the A2 motorway near Stryków and the exits that allow travellers to drive down a section and along other national and regional roads – noticeably impacts the range of the two-hour isochrone that reaches Toruń (cf. Stępniak and Rosik, 2013).

The accessibility of regional centres still demonstrates relatively large spatial disproportions (Fig. 5). In the west, the centre and the south of Poland, regional residents are offered conditions enabling fast travel to voivodeship capitals, which stems from the overlapping of two most crucial factors: the layout of the settlement network with, most frequently, a central capital of the voivodeship (which shortens the distance and, indirectly, also the travel time), and a better transport infrastructure when compared to the rest of the country (that enables faster trips to be made by private vehicles). The areas characterised by poorer accessibility to voivodeship centres are those territories that lack fast roads or have very few of them (e.g. city ring roads), and that impedes fast transport to the quickest reachable regional centres and/or puts at an disadvantage those settlements which are located at a significant distance from them (which most commonly is the effect of the spatial layout or hierarchy of the settlement network – in such regions characterised by a less concentric network such as the West Pomeranian Voivodeship).

A new period of the EU budget programming creates a chance for further spatial development of the network, which – to a large extent – will be based on its complementation, and thus, the ensuring of its continuity (Fig. 1). Broadly speaking, the planned system of express and motorways in Poland is expected to directly connect regional centres (cities – voivodeship capitals) with one another (for national connections) and with the European transport network (for trans-European connections). The final scope of the investment and the moment of its completion depends, of course, on many factors. They are both internal and external to the national transport policy. At the stage of implementation of a specific infrastructure investment, there are often problems with underestimating costs or inaccurate inventories at the planning stage. Key infrastructural investments are usually carried out in such long perspectives that it may even bring about changes in labour costs or building materials (we are currently dealing with that in Poland). In addition, there may be new key strategic investments that have an impact on the entire transport system of the country. In Poland, that

is the currently implemented project of the Central Communication Port. Transnational flows of people and loads can also change. Geopolitical changes may make one of the national investment plans more or less justified. Of course, the list of these factors is much more extensive, and one should be aware of them in the ex-post approach.

4. RESULTS

4.1. The central variant

As a result of the implementation of the planned system of expressways and motorways, the range of "fast-travel" isochrones to the capital city will be expanded mainly in the directions which so far have not been reinforced with the construction of expressways and motorways (Kielce, Lublin, Belarus, Kuyavia and Warmia), or whose technical conditions and fragmentariness (Częstochowa) restrict fast travel (Fig. 2).
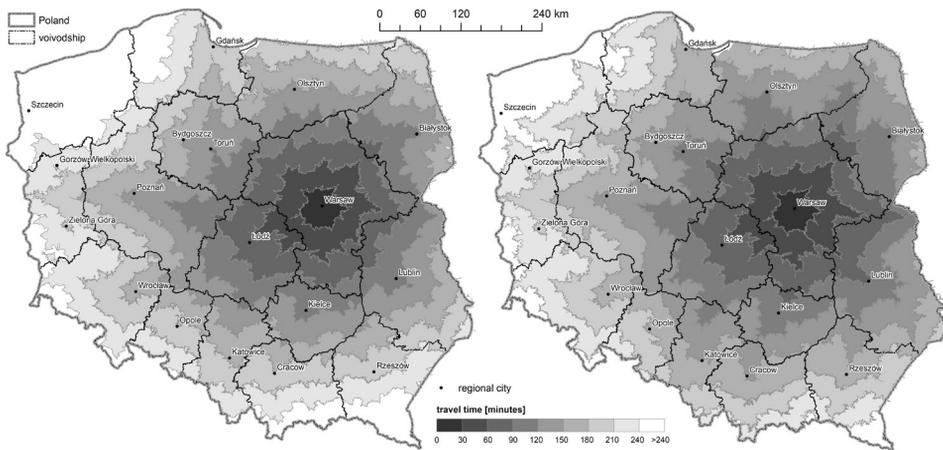

Fig. 2. Travel times to Warsaw in 2017 (left) and in the case of achieving the target layout of expressways and motorways (right)

Source: own work.

The construction of the planned express and motorways will mostly contribute to the approximation of Warsaw (in terms of travel time) to the regions of Subcarpathia, Lesser Poland, the Suwałki Lake District, and the eastern part of the West Lake District (Fig. 3).
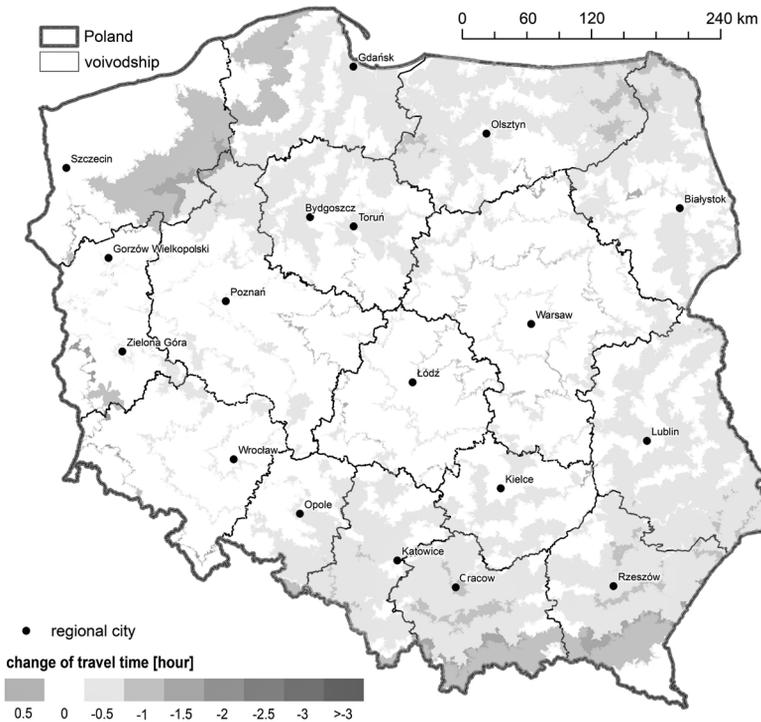
Fig. 3. Changes in travel time to Warsaw resulting from achieving the target layout of expressways
and motorways in Poland

Source: own work.

An increase in the accessibility of Warsaw will result in the growth of potential mobility of people living around the capital city. In particular, this will affect residents of those settlements whose current travel times to Warsaw are between 90 and 120 minutes (Table 1). Such an enormous change stems from the fact that road investments will greatly facilitate transport options with some (demographically) important centres – Toruń, Olsztyn and Białystok, and from an increase of the area covered by this isochrone. The planned investments will substantially expand the range of hour-long travel to Warsaw (in spatial, demographic and settling terms). This results mainly from the fact that these have a supralocal nature, and thus, their construction does not always involve an increase in accessibility between closely located centres. From the perspective of individual settlements, the expansion of the network of expressways and motorways may contribute to a decrease in their residents' accessibility to Warsaw, due to a negative "corridor effect", understood as a spatial barrier for perpendicular interactions (Komornicki *et al.*, 2013b). This phenomenon is, however, marginal in nature.

Table 1. Settlement units, the size of the population and business entities within the isochrones of access to Warsaw in 2017 and in the case of accomplishment of the target layout of expressways and motorways in Poland

Current accessibility			
Travel time [min]	**Number of settlement units**	**Population**	**Number of business entities**
30	636	2,552,501	552,973
60	4,026	3,788,804	662,263
90	10,267	7,039,259	963,268
120	18,332	10,814,321	1,302,919
150	27,019	15,530,213	1,822,760
180	35,004	21,922,584	2,493,655
210	42,735	30,543,491	3,426,299
240	47,813	34,852,819	3,850,226
>240	52,704	37,627,090	4,182,815
Target accessibility			
30	642	2,553,728	552,192
60	4,321	3,888,041	668,692
90	11,624	8,053,309	1,007,297
120	20,986	12,429,223	1,451,772
150	31,469	20,012,878	2,240,714
180	39,923	28,177,551	3,159,401
210	45,661	33,461,703	3,680,781
240	49,875	36,090,947	3,955,878
>240	52,704	37,627,090	4,182,815
Change (100% = present road network)			
0–30	100.9	100.0	99.9
30–60	108.5	107.9	106.6
60–90	117.0	128.1	112.5
90–120	116.1	115.9	130.9
120–150	120.7	160.8	151.8
150–180	105.9	127.7	136.9
180–210	74.2	61.3	55.9
210–240	83.0	61.0	64.9
>240	57.8	55.4	68.2

Source: own work.

As can be seen from the research conducted by Rosik *et al.* (2016), Warsaw, fulfilling its social role, becomes a generator of business trips, in the context of the potential that both generates and absorbs traffic. Therefore, one of the effects of the planned expansion of the transport network may be a potential increase in mobility resulting from the rise in accessibility. It is anticipated that it will, to a great extent, contribute to the improvement of the effectiveness of economic relations between the enterprises that operate within the territory marked by the three-hour isochrone, where a noticeable growth in their number will be recorded (by 26.7%).

Further expansion of the network of motorways and expressways in Poland will contribute to changes of traffic-flow vectors towards Warsaw. Spatially, these vectors are modified in two major types of regions, the first being regions with an undeveloped infrastructure of motorways and expressways. Only upon the implementation of the planned layout of roads will they be incorporated into the national network of motorways and expressways. This implementation will enable traffic flows to be channelled through new routes and national and regional roads to be relieved (Subcarpathia, Świętokrzyskie Voivodeship, Central Pomerania, Masuria). The second type are those regions with a well-developed infrastructure of motorways and expressways, where no new investments are planned. In their case, changes in traffic flows stem from expansions to the transport network which are sometimes planned several tens of kilometres away (Opolian Silesia and the complementation of the network with the central section of the A1 motorway).

Quantitative changes within traffic vectors indicate a substantial growth of density on the existing roads that serve vehicle traffic reaching Warsaw from the west (A2) and the south-west (S8). Due to the densification of the transport network, traffic on national and regional roads will be depleted. That will also refer to some motorways and expressways, since alternative and substitutive routes are to be built.

4.2. The interregional variant

The expansion of the transport network, the aim of which is to connect regional centres by means of a network of motorways and expressways, will – to the greatest extent – contribute to the improvement of the connections between regions located at the opposite sides of Poland (Fig. 4). In consequence, the largest beneficiaries of the planned expansion will be the cities located centrifugally (Olsztyn, Białystok, Lublin, Rzeszów, Wrocław, Zielona Góra, and Szczecin). The cities in central Poland will not improve their position, due the fact that their specific locations usually predestine their relatively high accessibility, and whose potential increase is connected with the development of road infrastructure leading to eastern regions.
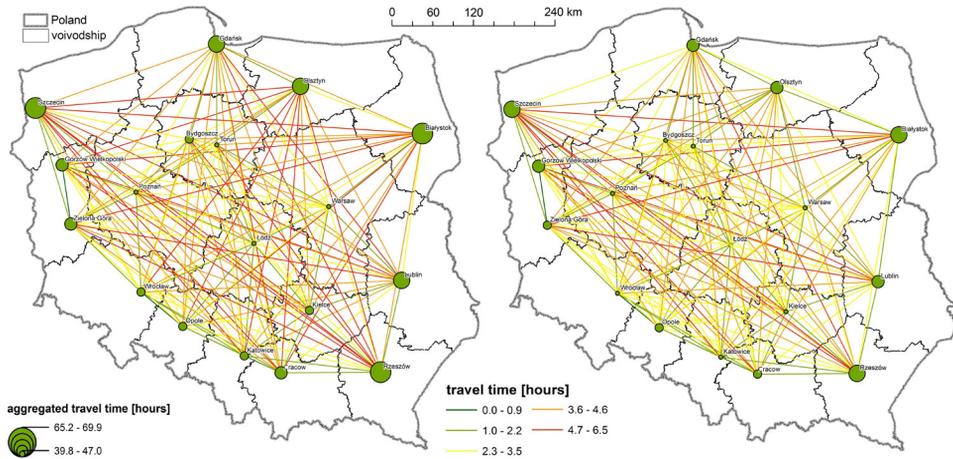
Fig. 4. Differentiation of bilateral and accumulated mutual time accessibility of regional centres in Poland in 2017 (left) and in the case of accomplishment of the target layout of expressways and motorways in Poland (right)

Source: own work.

4.3. The regional variant

In the intra-regional approach, the complementation of the network of motorways and expressways will contribute to the increase in accessibility of peripheral areas (Fig. 5), whose poor accessibility to-date has so far stemmed mainly from a poorly developed transport infrastructure. Despite the fact that poorly accessible regions, whose regional settlement networks do not take a concentric form, will be provided with the infrastructure of motor and expressways, their potential will still not be developed to a sufficient degree (i.e. below a 60-minute travel time to the nearest regional centre).

The areas which have already been characterised by decent accessibility will not undergo a substantial spatial transformation, with the exception of territories located in the vicinity of voivodeship capitals in eastern Poland, around which, proportionately, the largest number of new road investments has been scheduled. This is particularly visible in the north of Mazovia and in the south of the Warmian-Masurian Voivodeship. In this area, hourly isochrones of travel to the capitals of voivodships (Warsaw, Olsztyn, Białystok and Toruń) will overlap. This relatively arable area until now peripheral will become much more accessible.
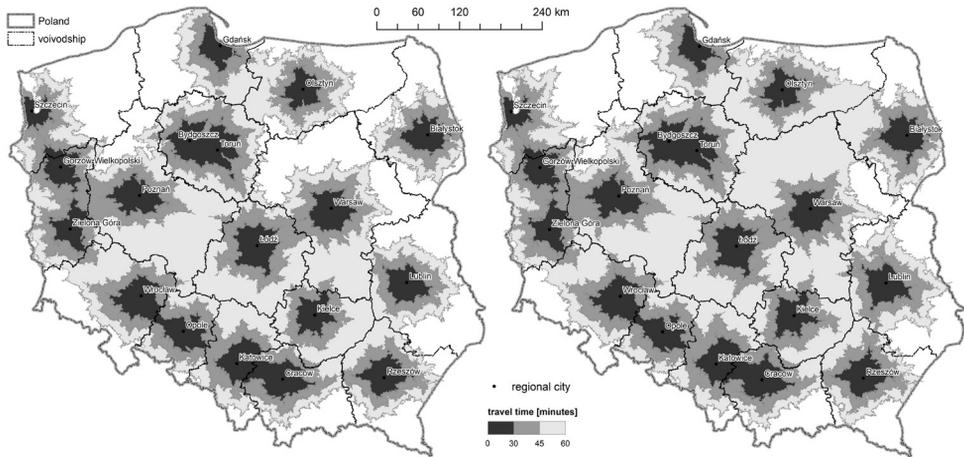
Fig. 5. Travel times to regional centres in Poland in 2017 (left) and in the case of accomplishment of the target layout of expressways and motorways in Poland (right)

Source: own work.

The implementation of the stipulations listed in the Polish normative acts, despite the relatively vast spatial scope, will result in a limited increase in the numbers of residents who are within the reach of the one-hour isochrone of travel time to the nearest regional centre, i.e. by as little as 4.7% (Table 2) on a national scale. Such a low growth rate of motility stems chiefly from the nature of the settlement network (spatial growth of accessibility will mainly refer to poorly populated regions). An even lower growth rate (3.5%) is reported in terms of potential mobility resulting from the operations of business entities, which so far have not been located within an hour's travel time to the nearest (timewise) voivodeship capital.

Table 2. Settlement units, population, and business entities within the isochrones of travel to regional centres in 2017 and in the case of accomplishment of the target layout of expressways and motorways in Poland

Current accessibility			
Travel time [min]	Number of settlement units	Population	Number of business entities
30	7,566	15,750,797	2,167,479
45	19,805	23,725,430	2,871,403
60	38,864	32,201,230	3,601,914
>60	52,704	37,627,090	4,182,815

Table 2. (cont.)

Target accessibility			
30	7,898	15,958,024	2,181,097
45	21,347	24,482,588	2,923,316
60	43,531	33,714,111	3,727,025
>60	52,704	37,627,090	4,182,815
Change (100% = present road network)			
0–30	104.4	101.3	100.6
30–45	109.9	106.9	105.4
45–60	116.4	108.9	110.0
>60	66.3	72.1	78.5

Source: own work.

Traffic flows directed at the fastest accessible regional centres will not demonstrate changes and, except for the region of Central Pomerania, they basically refer only to changes resulting from the fact that part of the traffic will move from lower class roads to the newly constructed expressways and motorways, which are frequently designed to run in the vicinity of alternative existing roads that take traffic heading towards a central city from the whole region (Fig. 6).

The most important changes will occur as far as the change in cardinal directions of traffic flows in Central Pomerania is concerned, where – as a consequence of the planned modifications – there will be a change in the fastest accessible voivodeship capital, from Szczecin to Poznań, with its resulting modification of the direction of the main traffic flow, from latitudinal (along the projected S6) to longitudinal (the proposed S11).

5. DISCUSSION AND CONCLUSIONS

The planned transport network, through increase in accessibility (the central variant), may offer induced mobility (a larger number of trips, including everyday commuting and business trips), provided that the growth of motility will manifest itself in the real-life phenomenon of mobility. This traffic will chiefly be taken by the network of expressways and motorways, which should relieve low-class roads. The opening of new (planned) sections of expressways and motorways will, to a minor extent, contribute to the fundamental changes in the directions of traffic flows, and the only transformations will apply to regions:

   – with a developed infrastructure of fast vehicle transport whose functionality is limited due to a lack of cohesion in further stretches,

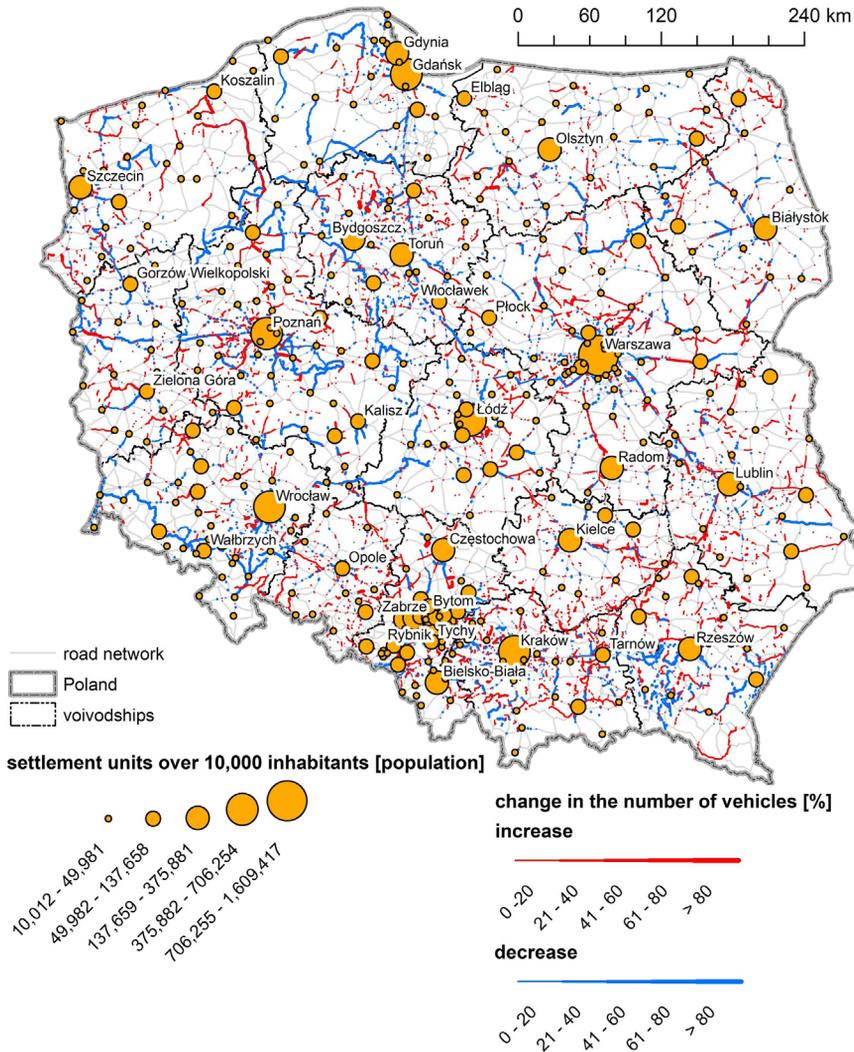   – without a developed network of expressways and motorways.

Fig. 6. Changes of network traffic flows to the most accessible regional centre in Poland as far as travel time is concerned

Source: own work.

The improvement of the accessibility of Warsaw and the increase in motility may result in numerous benefits for the Warsaw job market (by increasing the availability of labour force) due to the expansion of its spatial reach.

The increase in accessibility and its related mobility may result in the improvement of the conditions of running a business due to the optimisation of the processes related to transporting goods and making business trips.

Regionally, the expansion of the transport infrastructure will only slightly increase the direct (up to 45 minutes) transport accessibility of regional centres. Nevertheless, an increase of the spatial range of accessibility (of the influence radius) has been observed in terms of one-hour travel time to major regional cities. This increase does not entail substantial changes in potential mobility. No changes in the directions and the density of traffic flows towards voivodeship capitals (centres with the largest degrees of employment concentration and public benefit services, and strongest business connections) are anticipated, with the exception of Central Pomerania (an increase in the importance of Poznań at the expense of Szczecin).

As a consequence, the program of expansion of Polish expressways and motorways will be beneficial in the context of short-term spatial behaviours on a central and regional scale, including the transfer of transit traffic from lower category roads (often running through cities without bypasses) to high-speed roads with higher capacities. We expect that this infrastructure will trigger long-term spatial behaviours, including those related to the transformation of landscape management, which can bring social and economic benefits.

This article presented the research into the change of transport accessibility and potential mobility, based on the assumption that the existing land development and functionality remain unchanged. In reality, however, the expansion of transport infrastructure brings economic, social, demographic, and spatial changes, as was shown in studies related to such changes.

When it comes to the economy, these changes entail the economic growth of easily accessible regions, and thus, are related to the concentration of a larger number of business entities around transport corridors, including the development of logistics centres (Wiśniewski, 2015). Therefore, the economic dimension of the expansion of the Polish motorways and expressways ought to be greater than how it might appear based on the presented model-like approach.

At this point it must be mentioned that an increase in the accessibility to transport infrastructure does not lead, in itself, to a increase of territorial cohesion. As demonstrated by Gorzelak (2009), in low-cost countries (which in the EU include Poland) foreign capital places its investments in spots that offer better administrative conditions (i.e. which are better developed, i.e. big cities) and improved transport accessibility despite their relatively higher business costs when compared to peripheral areas. What is more, Rosik (2006) noticed that the development of a transport network in a country characterised by vast infrastructural delays (e.g. Poland) may be effective on a national scale, but it leads to further regional polarisation. Due to economies of scale, the implementation of an infrastructure with higher technical parameters often results in centralisation and poorer competitiveness of businesses from outside the region characterised by the highest level of accessibility (the core), since enterprises in smaller settlement units are incapable of competing with companies based in large centres, which have vaster local mar-

kets and greater access to workforce, services, infrastructure, etc. In a situation when two parts of the same region are integrated by new infrastructure, the core region demonstrates the so-called drainage tendency, i.e. it absorbs the economic potential of the whole region. Thus, from this point of view, the expansion of the network of roads characterised by the highest parameters in different regions of Poland ought to be considered as a positive phenomenon. The conducted research indicated that there will be a growth in the levels of accessibility and mobility, but it will be so spatially "fair" and non-revolutionary in its outcomes that it ought not to cause the drainage of the potential of areas characterised by lower levels of economic development. Instead, it will only fill the existing deficits in accessibility.

It is also quite common that the spatial dimension, followed by demographic and social ones, undergoes transformations that lead to suburbanisation and urban sprawl. Therefore, one ought to assume that the expansion of the range of a city's influence may facilitate these phenomena and, as a result, may also modify potential mobility, i.e. it may increase it.

The development of transport infrastructure (especially with the highest parameters) may have a varied impact on the socio-economic environment. Its impact can also have not only a positive character. As discussed, the drainage of resources from regions towards areas with better living conditions (e.g. higher salaries) will emerge. Such processes may consequently lead to the impoverishment of regions and the formation of internal peripheries. In addition, assuming that supply creates its own demand, the expansion of infrastructure can increase mobility by causing higher ecological loading. The accumulation of traffic on express roads and motorways with increased mobility can lead to lower resilience.

The increase in the potential of mobility may bring benefits for regional cities which can partially compensate the negative external effects of the demographic crisis recorded in Polish cities.

The expansion of the catchment area of regional cities may result in the enhancement of their competitiveness in certain sectors of the job market and high-order specialised services. A growth of the potential number of employees resulting from enhanced accessibility does not always translate into the accompanying development of the job market, since the proximity of the area to workplaces does not necessarily mean that its residents have access to those workplaces, as their qualifications may not correspond to the profiles of vacancies (Cervero *et al.*, 1995).

It is imperative to conduct further research that will take consider the travel model with the stipulated traffic-generating potentials and the distribution of traffic density within the network for individual destinations. As recommended by Rosik and Kowalczyk (2015), the next step ought to be the combination of a gravitational model and the model of potential, which – in the context of the currently implemented infrastructural investments stipulated in the regulation on the network of motorways and expressways – would provide information on the

impacts of the implementations of individual sections of the network upon changes in accessibility and mobility. A valuable extension of such an analytic research would also be the inclusion of vehicle flows in international traffic. The conducted study confirmed the thesis proposed by Rosik *et al.* (2016) that research related to the feedback between accessibility and mobility ought to focus on offering a methodology of a simultaneous analysis of research methods, attributes, constituents, dimensions, and conditions of accessibility in reference to the feedback between mobility and accessibility.

REFERENCES

BARADARAN, S. and RAMJERDI, F. (2001), 'Performance of accessibility measures in Europe', *Journal of transportation and statistics*, 4 (2/3), pp. 31–48.

BIOSCA, O., SPIEKERMANN, K. and STĘPNIAK, M. (2013), 'Transport accessibility at regional scale', *Europa XXI*, 24, pp. 5–17.

BIRR, K., JAMROZ, K. and KUSTRA, W. (2013), 'Analiza czynników wpływających na prędkość pojazdów transportu zbiorowego na przykładzie Gdańska'. *Prace Naukowe Politechniki Warszawskiej – Transport*, 96, pp. 19–29.

BLACK, J. and CONROY, M. (1977), 'Accessibility measures and the social evaluation of urban structure', *Environment and Planning A*, 9 (9), pp. 1013–1031.

BOCAREJO, S.J.P. and OVIEDO, H.D.R. (2012), 'Transport accessibility and social inequities: a tool for identification of mobility needs and evaluation of transport investments', *Journal of Transport Geography*, 24, pp. 142–154.

BOISJOLY, G. and EL-GENEIDY, A. (2016), 'Daily fluctuations in transit and job availability: a comparative assessment of time-sensitive accessibility measures', *Journal of transport geography*, 52, pp. 73–81.

BRUINSMA, F. and RIETVELD, P. (1998), 'The accessibility of European cities: theoretical framework and comparison of approaches', *Environment and Planning A*, 30 (3), pp. 499–521.

BRZEZIŃSKI, A. and WALTZ, A. (1998), *Budowa hierarchicznych modeli ruchu w sieciach drogowych*, Ph.D. thesis, Politechnika Warszawska.

CAUVIN, C. (2005), *A systemic approach to transport accessibility. A methodology developed in Strasbourg: 1982–2002*. Cybergeo: European Journal of Geography.

CERVERO, R., ROOD, T. and APPLEYARD, B. (1995), Job accessibility as a performance indicator: An analysis of trends and their social policy implications in the San Francisco Bay Area. University of California Transportation Center.

DALVI, M.Q. and MARTIN, K.M. (1976), 'The measurement of accessibility: some preliminary results', *Transportation*, 5 (1), pp. 17–42.

FORD, A.C., BARR, S.L., DAWSON, R.J. and JAMES, P. (2015), 'Transport accessibility analysis using GIS: Assessing sustainable transport in London', *ISPRS International Journal of Geo-Information*, 4 (1), pp. 124–149.

FRANSEN, K., NEUTENS, T., De MAEYER, P. and DERUYTER, G. (2015), 'A commuter-based two-step floating catchment area method for measuring spatial accessibility of daycare centers', *Health & place*, 32, pp. 65–73.

GACA, S., SUCHORZEWSKI, W. and TRACZ, M. (2008), *Inżynieria ruchu drogowego. Teoria i praktyka*. Warsaw: Wydawnictwo Komunikacji i Łączności.

GEURS, K.T. and RITSEMA VAN ECK, J.R. (2001), *Accessibility Measure: Review and Applications*. Bilthoven: RIVM. National Institute of Public Health and the Environment, Bilthoven.

GEURS, K.T. and VAN WEE, B. (2004), 'Accessibility evaluation of land-use and transport strategies: review and research directions', *Journal of Transport geography*, 12 (2), pp. 127–140.

GEURS, K.T., RITSEMA VAN ECK, J.R. (2001), *Accessibility Measures: Review and Applications*. RIVM report 408505 006, National Institute of Public Health and the Environment, Bilthoven.

GĘSIARZ, Z. (1982), *Zarys geografii transportu*. Warsaw: WSiP.

GORZELAK, G. (2009), 'Fakty i mity rozwoju regionalnego', *Studia Regionalne i Lokalne*, 2, pp. 5–27.

GOULD, P.R. (1969), *Spatial Diffusion*. Washington DC: Association of American Geographers.

GUTIÉRREZ, J., CONDEÇO-MELHORADO, A. and MARTÍN, J.C. (2010), 'Using accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment', *Journal of transport geography*, 18 (1), pp. 141–152.

HAKLAY, M. (2010), 'How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets', *Environment and planning B: Planning and design*, 37 (4), pp. 682–703.

HANDY, S.L. and NIEMEIER, D.A. (1997), 'Measuring accessibility: an exploration of issues and alternatives', *Environment and planning A*, 29 (7), pp. 1175–1194.

HANNAM, K., SHELLER, M. and URRY, J. (2006), Editorial: Mobilities, immobilities and moorings. Mobilities, 1(1), Routledge, Milton Park, pp. 1–22.

HANSEN, W.G. (1959), 'How accessibility shapes land use', *Journal of the American Institute of planners*, 25 (2), pp. 73–76.

HANSON, S. and GIULIANO, G. (2004), *The geography of urban transportation*. New York: Guilford Press.

INGRAM, D.R. (1971), 'The concept of accessibility: a search for an operational form', *Regional studies*, 5 (2), pp. 101–107.

KAROU, S. and HULL, A. (2014), 'Accessibility modelling: predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK', *Journal of Transport Geography*, 35, pp. 1–11.

KAUFMANN, V. (2002), *Re-Thinking mobility*, Aldershot: Ashgate.

KOMORNICKI, T. (2011), *Przemiany mobilności codziennej Polaków na tle rozwoju motoryzacji*. Warsaw: IGiPZ PAN.

KOMORNICKI, T. and ŚLESZYŃSKI, P. (eds.) (2009), *Studia nad lokalizacją regionalnych portów lotniczych na Mazowszu.* Warsaw: IGiPZ PAN.

KOMORNICKI, T., ROSIK, P., STĘPNIAK, M. and POMIANOWSKI, W. (2013a), 'Dostępność transportowa, czyli jak ocenić za pomocą modelu potencjału, które inwestycje są najważniejsze?' *Przegląd Komunikacyjny*, 12, pp. 18–22.

KOMORNICKI, T., ROSIK, P., ŚLESZYŃSKI, P., SOLON, J., WIŚNIEWSKI, R., STĘPNIAK, M., CZAPIEWSKI, K. and GOLISZEK, S. (2013b), *Impact of the construction of motorways and expressways on socio-economic and territorial development of Poland*. Warsaw: Ministry of Regional Development.

KOMORNICKI, T., ŚLESZYNSKI, P., ROSIK, P., POMIANOWSKI, W., STĘPNIAK, M. and SILKA, P. (2009), 'Dostępność przestrzenna jako przesłanka kształtowania polskiej polityki transportowej', *Biuletyn PAN. Komitet Przestrzennego Zagospodarowania Kraju*, 241, pp. 1–163.

KOZINA, J. (2010), 'Transport accessibility to regional centres in Slovenia', *Acta geographica Slovenica*, 50 (2), pp. 231–251.

MAKKONEN, T., SALONEN, M. and KAJANDER, S. (2013), 'Island accessibility challenges: Rural transport in the Finnish archipelago', *European Journal of Transport and Infrastructure Research*, 13 (4), pp. 274–290.

MARTELLATO, D., NIJKAMP, P. and REGGIANI, A. (1998), 'Measurement and measures of network accessibility: economic perspectives', *Transport networks in Europe: Concepts, analysis and policies*, pp. 161–180.

MÓDENES CABRERIZO, J.A. and CABRÉ, A. (1998), *Flujos espaciales e itinerarios biográficos: la movilidad residencial en el* área *de Barcelona*. Barcelona: Universitat Autònoma de Barcelona.

NEUTENS, T. (2015), 'Accessibility, equity and health care: review and research directions for transport geographers', *Journal of Transport Geography*, 43, pp. 14–27.

RODE, P., FLOATER, G., THOMOPOULOS, N., DOCHERTY, J., SCHWINGER, P., MAHENDRA, A. and FANG, W. (2017), *Accessibility in cities: transport and urban form. In Disrupting Mobility*. Springer International Publishing.

ROSIK, P. (2006), 'Efekty redystrybucyjne zmian regionalnej dostępności transportowej', *Studia Regionalne i Lokalne*, 1, pp. 65–82.

ROSIK, P. (2012), *Dostępność lądowa przestrzeni Polski w wymiarze europejskim.* Warsaw: IGiPZ PAN.

ROSIK, P. and KOMORNICKI, T. (2013), *Wpływ budowy autostrad i dróg ekspresowych na rozwój społeczno-gospodarczy i terytorialny Polski*, Ministerstwo Rozwoju Regionalnego, Warsaw.

ROSIK, P. and KOWALCZYK, K. (2015), *Rozwój infrastruktury drogowej i kolejowej a przesunięcie modalne w Polsce w latach 2000 –2010.* Warsaw: IGiPZ PAN.

ROSIK, P. and OPAŁKA, E. (2011), 'Szacowanie efektów projektów drogowych. Przykłady zastosowania modelu ustalania i prognozowania efektów z wykorzystaniem wskaźnika dostępności transportowej', *Ocena wpływu i prognozowanie efektów w badaniach ewaluacyjnych,* 8, pp. 93–117.

ROSIK, P., KOMORNICKI, T. and GOLISZEK, S. (2016), 'Modelowanie dostępności i mobilności w kontekście zróżnicowań regionalnych liczby ludności, PKB i spółek prawa handlowego', *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego*, 30 (4), pp. 21–34.

ROSIK, P., KOMORNICKI, T., STĘPNIAK, M. and POMIANOWSKI, W. (2013), 'Dostępność transportowa, czyli jak ocenić za pomocą modelu potencjału, które inwestycje są najważniejsze?' *Przegląd Komunikacyjny*, 12, pp. 18–22.

ROSIK, P., STĘPNIAK, M. and KOMORNICKI, T. (2015), 'The decade of the big push to roads in Poland: Impact on improvement in accessibility and territorial cohesion from a policy perspective', *Transport policy*, 37, pp. 134–146.

SALAS-OLMEDO, M.H., GARCÍA, P. and GUTIÉRREZ, J. (2015), 'Accessibility and transport infrastructure improvement assessment: The role of borders and multilateral resistance', *Transportation Research Part A: Policy and Practice*, 82, pp. 110–129.

SCHÜRMANN, C., SPIEKERMANN, K. and WEGENER, M. (1997), 'Accessibility indicators' *Berichte aus dem Institut für Raumplanung*, 39, pp. 1–102.

SPIEKERMANN, K. and NEUBAUER, J. (2002), 'European accessibility and peripherality: Concepts, models and indicators', *Nordregio Working Paper*, p. 9.

SPIEKERMANN, K. and WEGENER, M. (1996), 'Trans-European networks and unequal accessibility in Europe', *European journal of regional development*, 4 (96), pp. 35–42.

SPIEKERMANN, K., WEGENER, M., KVETON, V., MARADA, M., SCHÜRMANN, C., BIOSCA, O., SEGUI, A.U., ANTIKAINEN, H., KOTAVAARA, O., RUSANEN, J., BIELAŃSKA, D., FIORELLO, D., KOMORNICKI, T., ROSIK, P. and STĘPNIAK, M. (2015), *Transport accessibility at regional/local scale and patterns in Europe. TRACC executive summary and final report.* Luxembourg: ESPON.

STEPNIAK, M. and ROSIK, P. (2013), 'Accessibility improvement, territorial cohesion and spillovers: a multidimensional evaluation of two motorway sections in Poland', *Journal of Transport Geography*, 31, pp. 154–163.

ŚLESZYŃSKI, P. (2004), 'Demograficzne i ekonomiczne aspekty lokalizacji planowanego portu lotniczego w okolicach Warszawy', *Przegląd Komunikacyjny*, 43, pp. 13–19.

ŚLESZYŃSKI, P. (2007), 'Możliwości rozwoju regionalnych portów lotniczych w Polsce w świetle uwarunkowań popytowych', *Prace Komisji Geografii Komunikacji PTG*, 13, pp. 153–174.

ŚLESZYŃSKI, P. and KOMORNICKI, T. (2009), 'Wpływ rozwoju sieci drogowej na obszary rynkowe istniejących i planowanych portów lotniczych (2008–2015)', *Drogi: lądowe, powietrzne, wodne*, 9 (17), pp. 90–99.

TAYLOR, Z. (1999), *Przestrzenna dostępność miejsc zatrudnienia, kształcenia i usług a codzienna ruchliwość ludności wiejskie*. Warsaw: IGiPZ PAN.

TÖRNQVIST, G. (1970), 'Contact systems and regional development', *Lund Studies in Geography* B 35.

VAN WEE, B. (2016), 'Accessible accessibility research challenges', *Journal of transport geography*, 51, pp. 9–16.

VICKERMAN, R.W. (1974), 'Accessibility, attraction, and potential: a review of some concepts and their use in determining mobility', *Environment and Planning A*, 6 (6), pp. 675–691.

VICKERMAN, R., SPIEKERMANN, K. and WEGENER, M. (1999), 'Accessibility and economic development in Europe', *Regional studies*, 33 (1), pp. 1–15.

VIGAR, G. (2013), *The politics of mobility: Transport planning, the environment and public policy.* Routledge.

WANG, Y., MONZON, A. and DI CIOMMO, F. (2015), 'Assessing the accessibility impact of transport policy by a land-use and transport interaction model–The case of Madrid', *Computers, Environment and Urban Systems*, 49, pp. 126–135.

WIDENER, M.J., FARBER, S., NEUTENS, T. and HORNER, M. (2015), 'Spatiotemporal accessibility to supermarkets using public transit: an interaction potential approach in Cincinnati, Ohio', *Journal of Transport Geography*, 42, pp. 72–83.

WIŚNIEWSKI, S. (2015), 'Significance of trans-European transport networks for logistics centre localization as exemplified by the Łódź region', *European Spatial Research and Policy*, 22 (1), pp. 23–44.

WIŚNIEWSKI, S. (2016), 'Zmiana dostępności wewnątrzregionalnej województwa łódzkiego wskutek otwarcia wschodniej i zachodniej obwodnicy Łodzi', *Studia Regionalne i Lokalne*, 66, pp. 79–96.

WOLAŃSKI, M. (2010), *Rozwój infrastruktury transportowej w latach 2007–2010 w kontekście dotychczasowej realizacji Strategii Rozwoju Kraju 2007–2015 oraz kluczowych strategii sektorowych*, Ministry of Regional Development.

ŻAKOWSKA, L. and PUŁAWSKA, S. (2015), 'Transport accessibility – concepts and measures', [in:] GACA, S. (ed.). *Recent advances in civil engineering: road and transportation engineering*. Krakow: Politechnika Krakowska, pp. 189–209.