The Use of Potential Models in Research on Transport Accessibility of Knowledge and Innovation Centers on the Example of Poland

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Abstract In a knowledge-based economy, innovativeness is considered to be the main factor of regional development. Economic development on a regional and national scale is initiated in the urban agglomerations, in which there is a highest concentration level of knowledge, information, and tangible and intangible capital. The potential for innovation implementation is placed unevenly, which makes the spread of innovations and knowledge dependent on the transport accessibility of these places. The concept of transport accessibility and the possibilities for the use of potential models for the research on transport accessibility is presented in the article. It also covers the results of the research on the differences in transport accessibility of knowledge and innovation centers in different Polish regions which was based on the indicator of potential transport accessibility.

Keywords Transport accessibility · Potential models

Introduction

Modern socioeconomic development is based on knowledge and innovation introduction. Despite the extensive use of telecommunications technologies, spread of knowledge and innovation requires intensive personal contacts, which is achieved mostly through the connection between large city centers with fast public transport. New information and communications technologies are not pure substitutes of transport. Parts of knowledge in digital forms may be transferred over long distances with the use of information devices, but often there is no such possibility, and the need arises for infrastructure which would allow for direct human contact.

The increase in knowledge level and a fast spread of innovation requires regional cooperation of scientific activity and business centers with global economy centers,

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and theses connections may only be achieved with developed air transport or with high-speed rail. On the other hand, the diffusion of knowledge from main centers in the region into secondary areas is connected with the necessity of improvement of the transport infrastructure state on regional and local level, so as to broaden the range radius [1].

The goal of the article is to present the results of the research on differences in transport accessibility of knowledge and innovation in different Polish regions, which was based on the indicator of potential transport accessibility. The level of accessibility assessed with the use of that method takes into account not only the quantitative and qualitative state of the transport system, but also the potential for innovation in different regions.

The Concept of Transport Accessibility and the Methods for Its Measurement

The notion of accessibility is not unambiguous, and in the literature, there are many concepts which are connected with it. The word accessibility is derived from words access and ability and means the ability to access something [2]. Therefore, in the general meaning, the concept of accessibility is used regarding the easiness for population of a certain area to reach access to different kinds of activities, such as work, education, healthcare, shops, and cultural areas. One of the first definitions of accessibility as regards the spatial planning was proposed by Hansen (1959), who defined accessibility as a possible potential for interaction happening [3]. The potential for interaction is dependent on the characteristics of the transport system (travel time or costs of reaching the destination) and the manners of land management (quality of potential destinations) [4]. Transport systems are planned in such a way to facilitate participation in different spatially spread activities, which it takes various amounts of time to reach. In many scientific articles, the reviews of current definitions and connected measurement methods are presented, as well as ideas for the improvement of these methods and examples of their practical use [5–7].

Regardless of the adapted definition, in the literature, there are certain main groups of components which are the integral elements of transport accessibility, two of which can be seen as primary: the spatial use component and the transport component. Geurs and Ritsema van Eck distinguish four components which constitute the transport accessibility [8]:

- land-use component,
- transportation component,
- temporal component,
- individual component.

The land-use component takes into account the different spatial allocation of possibilities and places in which the society can satisfy their various needs. This is also the component which is described as the attractiveness of the locations as a destination in the transport system. The transportation component, also called the resistance of the space, shows how hard it is to travel between two places with a certain transport branch, which is dependent both on the equipment of transport infrastructure and the quality of services provided by the transport system. The temporal component includes the differences of accessibility levels on account of the time of day, week, and year. These differences are crucial, especially due to the fact that in certain periods, the congestion affects the extension of travel time and decreases the transport accessibility of destination. In turn, the individual component takes into account the socioeconomic characteristics of the transport user and his mobility. Those are three factor groups: the needs (which are the result of age, life phase, family status, income, and education), abilities (a result of physical condition and availability of different transport branches), and chances (a result of the income level, the part of budget allocated to travel and education level) [9].

Therefore, the transport accessibility is a concept which is both relative and contextual, which is why its definition depends on the breadth and the objective of the research. The notion is used regarding the transport system and the spatial planning as well as the behavior of the enterprises and the households. Apart from that, it is a subjective concept—perceived differently by different people and entities based on their experience and assessment. The same location can be assessed as available for some and unavailable for others, if only for different times and costs of travel.

Due to the fact that there is no universal definition of transport accessibility, many various indicators with different theoretical basis and complexity levels have been used in the empirical research [10]. Based on the literature review, six main research approaches to assess the transport accessibility can be marked off [11]:

- infrastructure-based accessibility which is assessed with the use of infrastructure equipment indicators of a certain region, e.g., the quantity and quality of spot and linear objects of transport infrastructure, that is, for example, the density of road and rail network or the capacity of airports;
- distance-based accessibility, in which the distance can be viewed as the physical distance (Euclidean), the real physical distance (e.g., the road distance), temporal (travel time) or economic (travel cost) between the origin point and the destination or collection of journey destinations, e.g., the total travel time to the ten largest European cities;
- cumulative accessibility or izochronic accessibility which is measured by an assessment of the set of journey destinations available in a given time, within a certain cost or travel effort, e.g., the number of citizens available within one hour, the number of high schools available within half an hour;
- potential accessibility measured by the possibility of an interaction between the travel origin and the set of travel destinations based on an assumption that the attractiveness of the destination is diminished by the extension of travel time or cost;

- person-based accessibility which takes individual preferences into account, analyzing the transport accessibility on an individual level, for example, the activities in which a certain person can participate within a certain time. That type of measures, based on behaviorism, was created in the time-space geography of Hagerstrand [12]. These measures include the temporal and spatial restrictions of human capabilities to function in a certain environment, such as the place and time of obligatory activities, the amount of free time and speed of travel available in the transport system;
- utility-based accessibility which analyzes the economic benefits which are the result of the access to spatially dispersed activity places. The transport accessibility is interpreted as a result of the choice made by the user of the transport system so as to maximize the utility out of the set of all possible solutions, which can all fulfill the same needs. This sort of transport accessibility measurement is connected with the transport demand modeling and the utility theory.

The further part of the article is concentrated on the modeling of potential accessibility, which was used to investigate the transport accessibility of knowledge and innovation centers in Poland. The use of potential model in the analysis of socioeconomic development level of regions was limited to two of its forms: the income potential and the population model, rarely regarding the market, work, or education services.

Potential Model in the Research on Transport Accessibility

The potential model belongs to the class of gravity models which are more and more used in the socioeconomic research. The essence of the potential model is based on the hypothesis that the mutual effects of two areas are directly proportional to their mass measured by, for example, their industrial production levels, economic potential, innovativeness level, population, and inversely proportional to their distance from each other. The notion of spatial potential is grasped in analogy to the potential of gravity field [13]. The potential determines the intensity of relations between the regions. It is a dependent variable not only of the size of the regions or the intensity of certain characteristics, but also their location regarding one another, that is their distance. The region as such might have a small internal potential but use the potential of other regions due to a beneficiary location in the regional system [14].

The use of potential models in scientific papers concentrating on the regional research on European countries has become common in the 1980s and 1990s of the twentieth century. The earliest research may be attributed to Keeble et al. [15], who used the potential for regional income as a basis of the availability of business activity and proceeded to use it investigate the changes of regional diversification of the European Union. On the other hand, Vickerman et al. [16] have assessed the

differences in regional availability of regions on a European scale based on the distribution of human potential and tried to establish the relations between the changes of accessibility and the economic development [14].

So far, the most complex research on transport accessibility for Europe was performed in the ESPON programme. The effect of the research was the calculation of indicators and the construction of maps of potential transport accessibility including the minimal travel time between the administrative type NUTS 3 units. The potential transport accessibility of an area has been established based on the economic and social potential, to which there is an easy access by transport routes of different transport branches. The indicator of potential transport accessibility specifies the number of attractive destinations which can be reached (or the population) weighed by the negative effect of travel time or cost [17].

In Poland, the research on the potential transport accessibility had been developed within the framework of economic geography before they were developed in economy. The Poznań center was famous for that research, from which Chojnicki [18], Czyż [19] and Ratajczak [20, 21] origin. In that center, the gravity and potential model was widely used for the research on transport accessibility so as to investigate the accessibility of cities and countries. An increased interest in the research on transport accessibility is visible in the recent years, which is undoubtedly a result of the Polish accession into the EU and a greater concern attributed to the problems of convergence and regional development. Broad research on the potential transport availability is conducted in the Institute of Geography and Spatial Organization of the Polish Academy of Sciences.

An Assessment of the Transport Accessibility of Knowledge and Innovation Centers in Poland

A methodology of the calculation of potential accessibility indicator was used so as to investigate the differences in transport accessibility of knowledge and innovation centers in Poland. The main assumption of the model is that the travel time between scientific centers of the high tier from different regions determines their access to knowledge and innovation. The indicator of potential transport accessibility determines the level of innovation potential which can be reached weighed by the negative effect of the travel time. A modified formula for the potential transport accessibility has been used in which, due to nature of the research, the internal potential of the region has been used.

$$A_i = P_i \exp(-\beta t_{ii}) + \sum_j P_j \exp(-\beta t_{ij}) \quad (1)$$

where

- A_i—access of the ith region to knowledge and innovation centers,
- P_i—innovative potential of the ith region,
- t_{ii}—travel time in the ith region,
- P_j—innovative potential of the jth region,
- t_{ij}—travel time between the ith region and the jth knowledge and innovation center,
- β—the parameter which determines the sensitivity to the travel time increase in the transport user.

In this view, the transport accessibility of the regions increases with the growth of innovative potential and decreases with the travel time increase. The transport accessibility of the knowledge and innovation centers is therefore determined with the use of variables, where

- the level of innovative potential is represented by the variable: the value of expenditure on R&D activity in year 2014 in a certain voivodeship[1];
- the travel time to different scientific centers has been established as the shortest possible travel time by road, rail, or air transport from the voivode city of the region.[2]

The β coefficient has been set at the level of 0.005 by analogy to the ESPON projects. Such a value means that for the travel time of zero minutes between the regions (which is not possible in reality but has been assumed in the region for the access to the internal potential of the region), the innovative potential in the destination region will be fully included into the indicator of potential accessibility in the region of origin. For the travel time of a bit over two hours, the weight is 0.5, and if the travel time extends to over five hours, the weight drops to 0.2. The data used to calculate the indicator of the potential transport accessibility is shown in Table 1.

The model of potential transport accessibility is not easy to interpret as it does not have any identifiable units. This is why, for clarity of the results, they are shown in a relative manner, i.e., regarding the average value of the whole research area, considering the average value as 100%. The values of potential transport accessibility of knowledge and innovation centers have allowed to group the voivodeships which are similar to each other regarding that indicator. The results of the research are graphically shown in the Fig. 1.

[1]The amount of expenditures on R&D has a high correlation with other variables which characterize a potential of knowledge and innovation, for example, a number of scientific workers, a participation in EU framework programs, and a number of students and graduates of high schools.

[2]In the air, transport has been imputed travel time between airports and city centers and 60 min necessary for check-in in domestic voyages.

Table 1 Value of R&D expenditures in year 2014 (in mln PLN) and the matrix of shortest travel times (in minutes) by road, rail, or air transport used to research the accessibility to knowledge and innovation centers in Poland

Voivodeship	R&D expenditures	Dolnośląskie	Kujawsko-Pomorskie	Lubelskie	Lubuskie	Łódzkie	Małopolskie	Mazowieckie	Opolskie	Podkarpackie	Podlaskie	Pomorskie	Śląskie	Świętokrzyskie	Warmińsko-Mazurskie	Wielkopolskie	Zachodnio pomorskie
Dolnośląskie	1 070.1		219	387	139	166	162	144	43	242	375	299	115	255	397	117	272
Kujawsko-Pomorskie	255.6	223		330	198	146	338	186	299	413	352	79	312	269	185	83	224
Lubelskie	690.7	384	330		403	232	239	133	341	149	234	308	279	145	281	318	473
Lubuskie	68.1	139	196	403		206	290	174	195	368	390	289	241	403	259	87	157
Łódzkie	703.7	166	146	232	206		181	67	169	285	256	206	154	129	235	126	288
Małopolskie	1 850.3	162	334	239	290	182		139	120	98	313	235	56	86	316	238	267
Mazowieckie	6 487.2	144	185	132	174	86	139		175	143	143	144	138	149	147	137	181
Opolskie	122.3	42	293	343	195	169	120	174		204	334	343	76	203	405	164	330
Podkarpackie	931.0	242	413	148	368	285	98	143	204		393	243	138	156	427	236	205
Podlaskie	233.4	408	350	234	413	256	320	143	365	393		316	296	315	213	336	498
Pomorskie	1 031.7	314	82	300	288	206	235	144	376	243	309		307	338	135	168	261
Śląskie	1 218.1	115	312	319	241	154	56	141	76	138	328	307		118	332	255	294
Świętokrzyskie	140.5	216	269	149	403	129	91	149	171	156	315	338	116		312	251	413
Warmińsko-Mazurskie	126.1	394	187	270	354	229	339	150	405	427	210	131	326	312		231	395
Wielkopolskie	1 059.3	124	84	317	93	126	238	137	175	236	302	167	238	251	234		140
Zachodniopomorskie	179.9	276	224	477	157	288	267	181	330	205	514	261	294	413	343	139	

The sums of travel times in rows and columns may differ, because the travel times by rail transport are often different in opposite directions. Travel times from a certain region are in the columns

Source Own elaboration on the base [22–25]

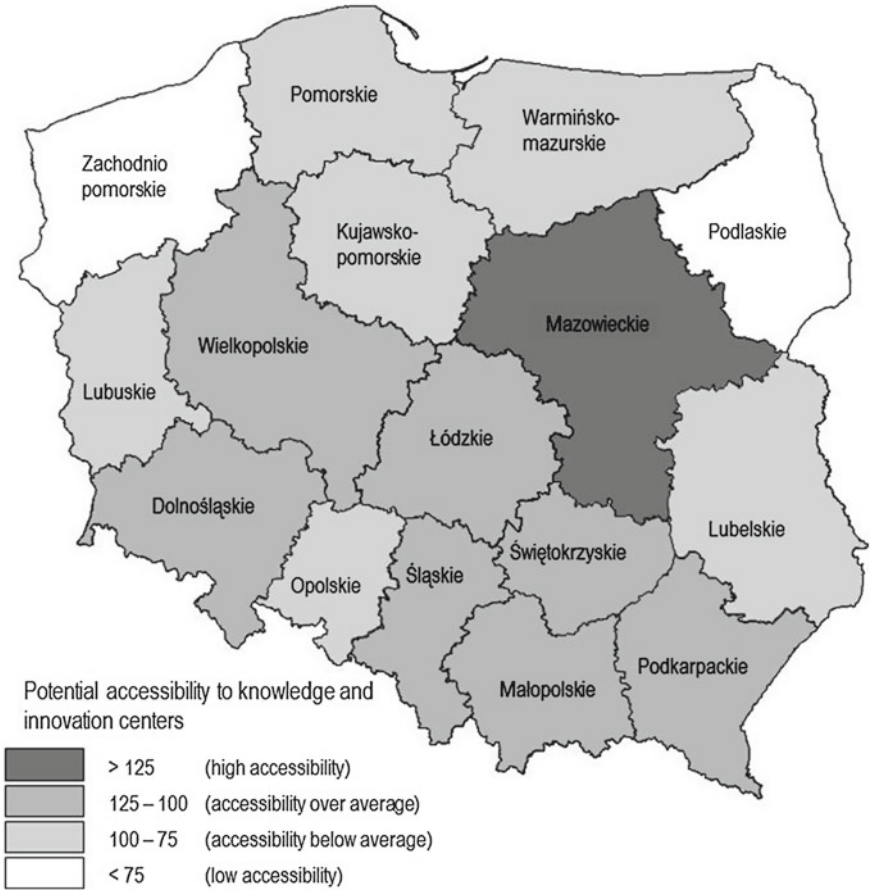

Fig. 1 Map of potential accessibility to knowledge and innovation centers in Poland. *Source* Own elaboration

The areas in which the innovative potential of the knowledge-based economy is concentrated are metropolises and metropolitan areas. The internal potential of the region and the travel time to other largest metropolises has the prevailing effect on the transport accessibility level of the regions.

The expenditures on R&D in Poland are very unevenly dispersed, and the Mazowieckie Voivodeship is significantly dominant (40.1% of the national scale in 2014). The Małopolskie Voivodeship is also significant and has a participation level of 11.4%. The following voivodeships for which the participation levels are about 6–7% are as follows: Śląskie Voivodeship, Wielkopolskie Voivodeship, and Pomorskie Voivodeship.

It is worth mentioning that in the abovementioned regions, the potential transport accessibility to knowledge and innovation centers is above the country average (except for the Pomorskie Voivodeship). The Pomorskie Voivodeship is characterized by a below average accessibility to knowledge and innovation despite the fact that the Tricity Metropolis is the region. In the voivodeship, the R&D expenditures are over 1 bln PLN, just as in the Dolnośląskie and Wielkopolskie Voivodeships, but the travel time to other research centers is relatively long due to a peripheral location in the country. On the other hand, the Łódzkie and Świętokrzyskie Voivodeships have lower R&D expenditures but benefit from the vicinity of regions which invest more. The lowest transport accessibilities are shown by the Zachodniopomorskie and Podlaske Voivodeships in which low R&D developments are accompanied by a long travel time to most important metropolises.

Summary

Under the conditions of knowledge-based economies, innovativeness is considered to be the most important factor of regional development. Therefore, much of the scientific research is concentrated on the ability to increase the level of innovativeness and the diffusion of knowledge and innovation. Modern development processes occur to a high extent in the system of enterprises, research institutes, public administration, and people initiatives network. That is why the development of the economy starts in the areas in which there is a highest level of concentration knowledge, information, and intangible and tangible capital. Furthermore, the spread of knowledge and innovation from the main areas of their development to the regions which are located further away will depend highly on the quality and effectiveness of the transport system.

Transport determines the knowledge transfer and the diffusion on innovations. That statement holds both for the passenger transport which allows the share of unstructuralized knowledge during personal contacts and for the cargo transport which allows the transport of, for example, books, documentation and data carriers. Apart from that, transport, despite the development of telecommunications technologies, determines the willingness to cooperate between the enterprises and between the enterprises and R&D entities. Decent transport accessibility is a key factor here.

In the article, the broad possibilities for the use of potential models for the research on transport accessibility were presented. The model was then used to analyze the diversity of transport accessibility to knowledge and innovation centers in Poland. The research has shown that there are significant differences in that regard. It is mostly the result of the concentration on R&D expenditures in scarce metropolises and the differences in the communication of different regions with these metropolises. Further activity concentrated on the improvement of the innovativeness of all the regions should take the transport factor into account.

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