Vol. 30/2022 No. 2

MORAVIAN GEOGRAPHICAL REPORTS

ÚGN

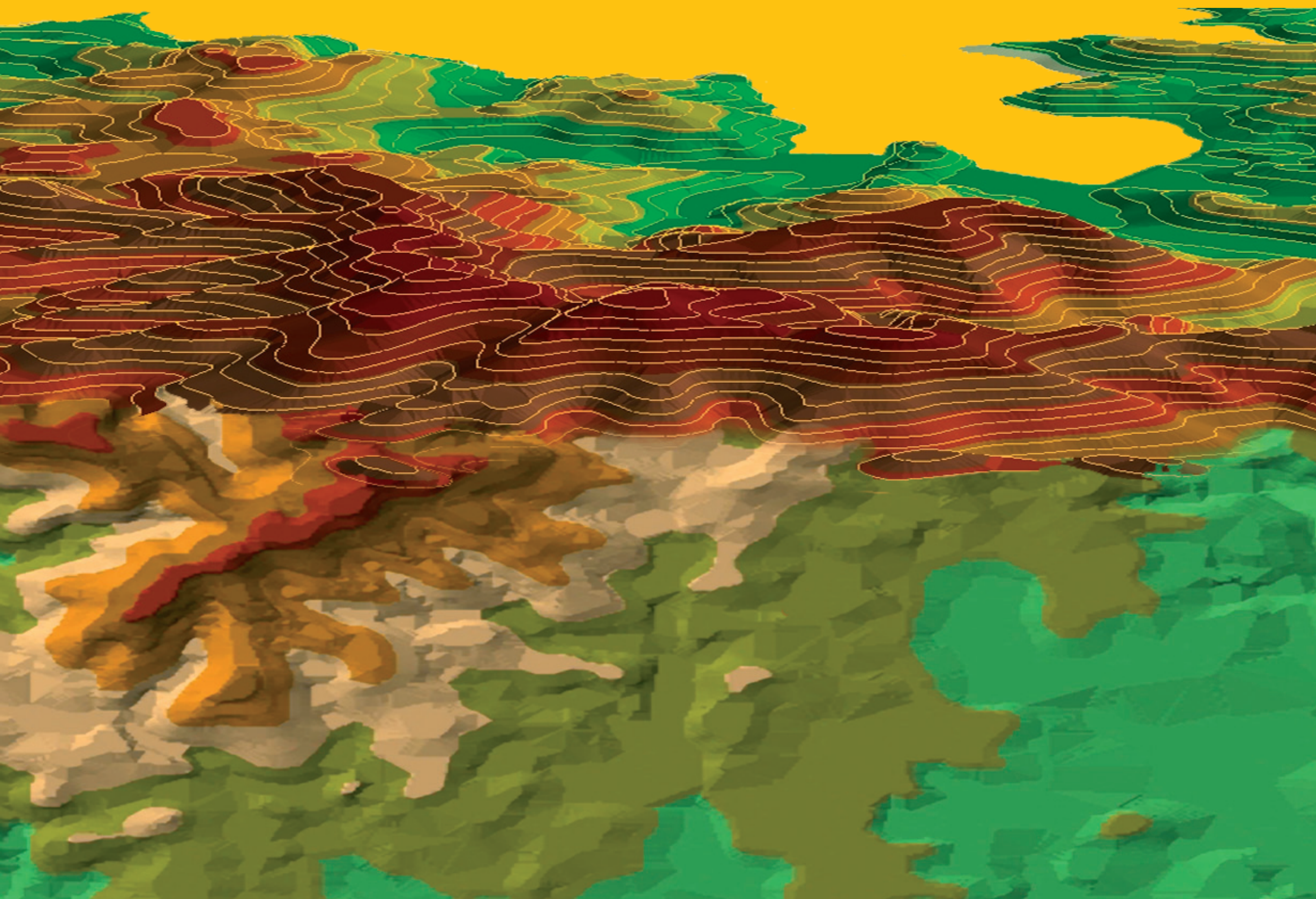


Fig. 14: An example of “rural” Facility for Seniors (Geria n.o.) in municipality Vyšná Jablonka (district Humenné) – it is located in former customs administration building in a beautiful quiet frontier rural area and its existence caused a revival of public events (Photo: J. Nestorová Dická)

Fig. 15: Facility for Seniors (Jeseň-Košice n.o.) in the city Košice is located in the busy central part of the metropolis in a polyfunctional building near the hospital (Photo: P. Gurová)

Illustrations related to the paper by J. Nestorová Dická and P. Gurová

MORAVIAN GEOGRAPHICAL REPORTS

Scientific papers:

PUBLISHER

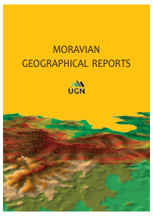
The Czech Academy of Sciences, Institute of Geonics (ID: 68145535)
Department of Environmental Geography
Drobného 28, 602 00 Brno, Czech Republic
(e-mail) mgr@geonika.cz
(home page) http://www.geonika.cz

ACCESS TO THIS JOURNAL

Information on the journal´s aims and scope, instructions for authors, calls for special issues, and full contents are available free online at:

http://www.geonika.cz/mgr.html
https://content.sciendo.com/view/journals/mgr/mgr-overview.xml

ISSN 2199-6202 (Online)



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics
journal homepage: http://www.geonika.cz/mgr.html
doi: https://doi.org/10.2478/mgr-2022-0005

The sustainability of social care in Slovakia: Modelling the existing network of residential social facilities for future senior populations

Janetta NESTOROVÁ DICKÁ [a] *, Patrícia GUROVÁ [a]

Abstract:

The possible availability of residential long-term care for seniors in the regions of Slovakia in the period to 2040 is evaluated in this contribution. The study identifies risk in the availability of residential care concerning the future development of the senior population. To highlight the potential risk for regions, three model projections are used. A factor analysis with two-by-two classifications was employed to identify the risk in the regions in terms of the availability of residential care. Due to the expanding senior population in Slovakia, maintaining the current capacity of residential facilities would significantly deteriorate the availability of social services. If the current ratio of residential care capacity to the size of the senior population is maintained, the number of beds will have to increase by 56% by 2040. Demographic ageing is a current challenge for public policy and requires searching for solutions to ensure the quality of social care for the elderly in every society. Our research shows that the risk in the regions of Slovakia varies depending on the existing capacity of residential facilities and the forecasted senior population.

Keywords: *seniors, population ageing, social care, residential facilities, modelling, regions, Slovakia*

Article history: *Received 13 December 2021, Accepted 6 June 2022, Published 30 June 2022*

1. Introduction

Knowledge of population development, demographic processes, and their impact on the functioning of individual spheres of the state are essential to ensure sound financial investment. Therefore, there is a current research interest concentrated on solving problems caused by growth in the senior population. Population ageing is a global problem, with intensive ageing processes recorded in almost all developed countries. There is an ongoing demand for reliable data and performance criteria as the elderly industry expands and diversifies.

The world's population is ageing rapidly. The 2019 Revision of the World Population records that the population aged 65 and over is growing faster than all other age groups. One in seven people in the world will be over the age of 65 (14%) by 2040, an increase from one in 11 in 2019 (9%). In addition, Šprocha et al. (2019) report that one in four people in Slovakia will be over age 65 by 2040, an increase from one in six in 2019. Based on the medium scenario population forecast for Slovakia, the proportion of seniors is expected to be 26%, with more than 1.4 million people who may eventually need special care. Evidence of an increasing longevity accompanied by an extended period of good health is scarce (Beard et al., 2016). The senior population will need a corresponding network of social and health facilities with supportive fields or ambulance services. Many countries are already resisting political or fiscal pressures on public health, pensions, and social protection systems for a growing elderly population. The problem is the increasing number and proportion of seniors in the population and increasing life expectancy. The forecast of Šprocha et al. (2019) reported an increase in the population of 80-year-olds in Slovakia from the current 3.4% to 8.4% by 2040, and the number of 100-years-olds will grow more than six times.

Thus, we observe that decreased fertility and improved survival into old age contribute to ageing. We record improvements in life expectancy at birth and even more rapid advances in life expectancy at older ages. According to the development of the Slovak population's mortality rates, by 2040 the life expectancy at birth could increase by four years for men and almost three years for women. Similarly, at the age of 65, there will be a continuously extended life

[a] Institute of Geography, Faculty of Science, Pavol Josef Šafárik University, Košice, Slovakia (*Corresponding author: J. Nestorová Dická; e-mail: *janetta.nestorova-dicka@upjs.sk*)

expectancy, so future seniors in 2040 could face nearly 18 years for men and more than 21 years for women (Šprocha and Ďurček, 2019). The situation is similar in the neighbouring Czech Republic, Poland and Hungary and other post-socialist countries (Kačerová et al., 2012; Šidlo et al., 2020).

The increase in the senior population implies immediately the availability and sustainability of social and health care. Moreover, services for the elderly aged 65 and over are already in high demand and expected by seniors (Szebehely and Trydegard, 2011). Slovakia provides several forms of social care for seniors, and the Ministry of Labour, Social Affairs and Family offers a regional overview of social service providers through a central register.

The worrying statistics and prognoses led to this investigation of current and future senior aged care in Slovakia. The research focuses on long-term residential care for seniors in social facilities with 24-hour care. It is uncertain if the current network of residential facilities in the regions of Slovakia will be sufficient because of the growing senior population. This paper will review the current and prospective availability of residential care in the districts of the Slovak Republic. The research explicitly models the availability of social services for seniors based on the forecast senior populations in Slovak regions by 2040. The population redistribution in these regions is influenced by migration and natural population movements (Bezák, 2011; Novotný, 2011, 2012; Pregi and Novotný, 2019). These influence changes in the population age structure, the size of human capital and demands for social services in different districts. Therefore, the ultimate research results will establish the sustainability of the social facilities' current capacities that provide residential care to the changing senior populations in the regions of Slovakia. We will thus identify the regional risks involved in the future development of the senior population and the availability of residential care.

2. Theoretical framework

Demographic changes since the mid-twentieth century have been triggered by the so-called 'age of ageing' (Magnus, 2009). Longer life expectancy and advancement in health services have led to increasing senior populations (Zainol and Pettit, 2016). Demographically, the concurrent fall in fertility rates and increase in life expectancy is resulting in a gradual increase in the proportion of seniors in many countries' populations. This change increases the burden on the economically productive population to fund sustainable social security programs, especially to cover pensions and senior social care. Studies of the impact of these changes in different societal areas have subsequently increased.

Although population ageing is a global phenomenon, data from the 2019 Revision of the UN World Population Prospects indicates that the situation in European countries is the most difficult (Phillips and Feng, 2017; Benítez-Aurioles, 2018; Li et al., 2019; Kluge et al., 2019). Moreover, the latest EUROPOP2019 population forecasts indicate that the ageing rate is increasing. Hewitt (2008), therefore, declares that a 'demographic time bomb' is ticking away in Europe, and preoccupation with the sustainability of seniors' social care in social debates is growing. A shrinking young labour force and a growing pool of elderly and retired is seriously threatening the long-term financial sustainability of public social and health insurance funds (Carr, 2007; Lin et al., 2010; Tediosi and Gabriele, 2010; Feng et al., 2012; Rechel et al., 2013; Beard et al., 2016; Woo, 2018).

A growing senior population increases the demand for social services and the costs of social care provision. Therefore, the availability of social services in state territories becomes a primary efficiency provision, which forms an essential part of this research. Vaňková and Vavrek (2021) evaluated the availability of social services and factors affecting accessibility in districts of the Czech Republic, and they also emphasise the state's responsibilities for ensuring the availability of social services, having established powers in the areas of planning, coordination and evaluation. Social policy, public funding, and regional local conditions represent strategic resources affecting the availability of social services.

The spatial distribution of the senior population and institutional social care for the seniors in Slovakia has regional specifics, reflecting the different levels of population ageing. In line with Šprocha and Ďurček (2019), the senior population has the highest representation especially in western and central Slovakia, except in the surroundings of Bratislava and the northern districts. The opposite situation is seen especially in the East Slovak districts with a significant concentration of the Roma population (Šprocha and Bleha, 2017; Nestorová Dická, 2021) and the north of central Slovakia. The outlook for 2040 predicts an increase in the senior population in all regions of Slovakia, especially in the regions where a smaller representation of this population today is registered. A reversal of the trends of the senior population can also be observed in urban and rural environments. Bleha et al. (2020) state that urban populations are older on average and age faster than rural areas. Until 2012, the Slovak senior population was dominant in the rural areas. At the present, population ageing is a common feature of all regions, but in the urban environment, the increase is evident, especially in larger cities with over 50,000 population. This situation is also copied by the level of equipment of institutional residential social care for the seniors. This situation then also reflects on the level of equipment for institutional residential social care. Today, there is an expanded network of social facilities with higher capacities in regions with larger urban cores and senior populations. Regions of self-governing cities have the highest representation but it is also seen in districts such as Medzilaborce and Myjava, where the level of the senior population was already well above the Slovak average at the beginning of the millennium.

The Supreme Audit Office of the Slovak Republic (SAO SR) published its final report on senior social services in 2018. Their report stressed that senior residential care demand in Slovakia exceeded the current placement capacity. Moreover, the waiting-list is growing exponentially. Vitorino et al. (2013) and Del Duca et al. (2012) consider seniors with advanced age a strong predictor of institutionalisation. The risk of functional incapacity and the development of chronic diseases in the elderly is greater. For that reason, we claim that the risk of institutionalisation at most doubles with every decade.

On the other hand, healthy ageing is a global priority, so it is essential to identify the determinants of healthy ageing. In line with Klusmann et al. (2021), such modifiable determinants may draw on improvements in the health care system, improvements in the built environment, or they may pertain to improving one's behaviour to promote healthy ageing outcomes. To support people to age healthily, however, policies and programs must translate the knowledge that a certain change in behaviour is important for healthy ageing. Because of WHO's 2015 world report on ageing and health, "healthy ageing" is defined as the "ongoing process of developing and maintaining the functional ability that enables wellbeing in older age". This definition distinguishes the three domains of healthy ageing: intrinsic capacity, functional ability, and environments, as biopsychosocial components of healthy ageing. WHO describes this functional ability (to meet their basic needs; to learn, grow and make decisions; to be mobile; to build and maintain relationships; to contribute to society) as being formed by interactions between intrinsic capacity and environmental characteristics (Rudnicka et al., 2020). The intrinsic capacity includes the mental and physical capacities of a person. The environmental characteristics are related to home, community, and society. Using Halfon and Forrest (2018), the research on a theoretical framework of life course health development (LCHD) is demonstrating how complex developmental processes integrate a range of behavioural, social, and environmental influences that modify gene expression, modulate physiological and behavioural function, and dynamically shape different pathways of health production.

Szüdi et al. (2016) add that historical, demographic, economic and political factors have forced the need to transform care services for seniors in Slovakia. According to Ludvigh Cintulová and Buzalová (2021), the fundamental changes in social services in Slovakia are based on the historical development of social services, the legislative framework, reflecting changes in funding, social quality standards and provision of human resources, the functionality and sustainability of social services. Similarly, amendments have also impacted the following planning, development and management of social services, which have had both positive and negative impacts on the current state of social services. The authors then indicated the negative impacts emanating from unstable political and economic situations, law changes, regional differences in public resources, social and human capital, and the lack of connection between senior health and social care.

The social services sector in Slovakia today does legislate Act No. 448 of 2008. This act provides the entry of non-public social service providers into the Slovak market. Repková and Brichtová (2011) noted that the previous reform did not make it possible to finance a non-public provider from public sources. Receivers of social services can now choose providers established by the municipality, a higher territorial region or from the non-public sector by civil associations, not-for-profit organisations, the church or even a company limited by shares. Adoption of this 2008 law in Slovakia led to long-term residential care for the seniors performed in the "facility for the seniors", which in research debate (e.g. Chappell et al., 2004; Lestage et al., 2008; Munyisia et al., 2011; Lim et al., 2013; Nikmat et al., 2015; Berg, 2021) are often referred to as a Care home, Nursing home or Residential care home. The names of these facilities may vary slightly from country to country. The development of the system of social care for the seniors in Slovakia has been presented elsewhere in more detail: see Káčerová et al. (2021), Ludvigh Cintulová and Buzalová (2021), Lukáčová and Novotná (2020), Kubalčíková et al. (2017), Szüdi et al. (2016), Kačerová et al. (2013), Krajňáková (2009).

Lukačová and Novotná (2020) record that the facilities for seniors in Slovakia most identify with the term 'Residential home care'. These facilities provide long-term residential services with nursing care and a diverse range of services under "one roof", with a maximum of 40 social service recipients in one facility building. There were 486 residential facilities (RF) for seniors with a total capacity of 19,529 placements registered in Slovakia at the end of 2019. Šídlo and Křesťanová (2018) considered that the development of RF capacities depends on the number and proportion of seniors, on their health status, their housing, economic situation, and disposable income, and eventually on the extent of family support and/or other forms of social support.

The process of population ageing in Slovakia and its regions is a changeless and currently relatively dynamically deepening phenomenon. Šprocha and Ďurček (2019) point to the continuous persistence of low fertility, declining reproductive potential, and continuing prolongation of life with slight migratory increases and the existence of significant intergenerational inequalities in the age structure of the Slovak population. The results of all known domestic (Šprocha et al. 2019) and foreign population forecasts (EUROPOP, 2019) confirm the continuation of ageing. Šprocha and Ďurček (2019) assess in detail the dynamics and level of aging from a regional perspective in Slovakia and with a view to 2040.

3. Data and Methods

Research results reported in this study are based on data publicly available from the Ministry of Labour, Social Affairs and Family of Slovakia, Demographic Research Centre INFOSTAT and the Statistical Office of Slovakia. The fundamental indicators map seniors' residential care based on knowledge of the existing capacity of RF, the age structure of seniors in the region with projections to 2040. The future development of the investigated phenomena, according to Šídlová Kunstová and Šídlo (2016), is 'estimated by considering the interaction between two groups of variables: input assumptions which can cover the 'what if' scenarios in the model characteristics described below, and these may not be realistic, and the expected development in the population number and structure provided by initial senior population forecasts'. According to the baseline scenario variant, the researchers used population forecasts with a 2040 medium-term view at the LAU1 level compiled by Šprocha et al. (2019). Šídlo et al. (2020) consider this baseline scenario variant as the most likely scenario to estimate the composition of the population by age.

The fundamental spatial research unit is at the LAU1 level, covering the districts of Slovakia. For the needs of the research, Bezák (1996, 2001) suggested merging the curious city districts of Bratislava and Košice into two separate regions. Hence, the set of basic spatial units consisted of 72 districts, which are diverse in population size or spatial size. Outside Bratislava and Košice, the districts of Prešov, Nitra and Žilina have more than 150,000 inhabitants. On the other hand, small districts have less than 20 thousand inhabitants: Banská Štiavnica, Turčianske Teplice and Medzilaborce. Bezák (1996, 1997) pointed out this regional inequality and injustice. The data needed for this regional analysis is only available for these spatial units. Model projections of the availability of social services at the lower levels of the landscape's regional structure raise the profile of the actual situation in particular regions. It provides opportunities to seek solutions to the following state.

The research procedures adopted for the study's requirements are divided into two key stages. The initial research phase predicted the capacity of seniors' RF in Slovakia based on knowledge of the existing capacity in the region and the development of the senior population. This analysis focused on creating model projections of the availability of seniors' long-term residential care through the existing capacities of RF for senior population changes in the regions by 2040. The observation used three models designed by Šídlová Kunstová and Šídlo (2016) and Šídlo and Křesťanová (2018). In addition, Bleha et al. (2018) consider that the results of population forecasts are, and will be, important in planning several spheres of societal functioning, especially economic and social development, labour market and pensioner's security schemes.

The creation of model projections with a medium-term estimate required forecasts of the senior population and the current number of capacities in the RF for the districts of Slovakia:

1. Model "A" assumes that the current network of residential facilities and their capacities in the region will be maintained throughout the projection. The basis of the model is an estimate of how much the theoretical number of seniors per bed in the RF will increase. The model indicates a changed demand from potential customers per bed. The number of clients vying for each available bed varies depending on quantitative shifts in the number of seniors by age;
2. The second model, "B", assumes that the proportion of seniors placed in RF is maintained throughout the projection period, i.e. the rate of service users in the region. The basis is an estimate of what the region's total capacity should be if the same proportion of seniors should be served as recorded at the 2018 projection outset; and
3. Model "C" is based, similarly to model B, on the assumption of maintaining the share of the placed senior population in the number of seniors in the relevant region of Slovakia, but not the population aged 65 and over as a whole, but individual shares regarding age categories. As in the previous model, it is based on maintaining constant age proportions of clients served in RF to the corresponding senior population but in individual age categories. This model can assume that the results better reflect the changes in the senior age structure. Hence, they will indicate a greater need for additional places in RF. Model C more accurately estimates the total capacity required for RF in a region. Specific age groups of clients in model C are expressed by the "weight" for each age group in RF.

The proportions of placed clients with respect to the age categories of seniors obtained from field surveys are given in the explanations with the mathematical formulas of models (1)–(3). The field surveys carried out by the authors themselves have taken place over the years 2019 and 2020. Ninety-six subjects (21%) out of 486 facilities for seniors in Slovakia were addressed to provide the required information. For the sake of representativeness, the random selection was managed in terms of representation according to the capacity of the facility, rural-urban and equal representation from the regions of western, central, and eastern Slovakia. Only 64 entities (13%) provided the requested information. Finally, the data set met the condition of representativeness. The obtained representation of clients according to age categories in the facilities was the basis for determining the rate of service users from the relevant age categories of seniors in the districts of Slovakia (3'). Thus, the created weights representing the rates of service users according to the clients' ages were assuming 100% occupancy of the facilities in the region.

The study investigated model predictions for the age of the seniors in the following two variants: a = 65+ and a = 75+. A two-option solution to the problem stems from the high probability that numerically strong generations (born in the 1970s – pro-natal measures of the previous political regime) will live to an even older age. Concurrently, 'Health at a glance: Europe (2020)' suggests that the population of Slovakia can expect to live free of disability for approximately four years after reaching senior age. This trend is expected to continue, so the senior population will live in health for several years. Studies also testify to improved seniors' health status and consequent prolongation of healthy years in senior age without the need for social or health care (e.g. Jagger et al., 2008; Welsh et al., 2021; Newton, 2021; Santos et al., 2021). The following weights of older peoples' age groups proposed for the option 75+ are based on the previous trends and predictions of decreasing rates of service users of younger seniors in the RF. Therefore, the weight of a2svk1 was a significant reduction, but not zero, assuming that a small proportion of younger seniors would need social care. The magnitude of the weight reduction value a_{2svk1} was then evenly distributed to the weights a_{2svk2}, a_{2svk3} and a_{2svk4}.

$$M_A^{y,r} = \frac{PS_a^{y,r}}{k^{y=2018,r}} \tag{1}$$

$$M_B^{y,r} = PS_a^{y,r} \cdot \frac{k^{y=2018,r}}{PS_a^{y=2018,r}} \tag{2}$$

$$M_C^{y,r} = \sum_{i=1}^{n} PS_{ai}^{y,r} \cdot w_{ai}^{y=2018,r} \tag{3}$$

$$w_{ai}^{y=2018,r} = \frac{a_{Svk,i} \cdot k^{y=2018,r}}{PS_{ai}^{y=2018,r}} \tag{3'}$$

where:

$M_A^{y,r}$ = Model A in year y in region r;

$M_B^{y,r}$ = Model B in year y in region r;

$M_C^{y,r}$ = Model C in year y in region r;

Y = 2018, … , 2040 and r = 1, ... , 72;

$PS_a^{y,r}$ = number of seniors (a_1 = 65+, a_2 = 75+) in year y in region r;

$k^{y,r}$ = capacity in year y = 2018 in region r;

$PS_a^{y=2018,r}$ = number of seniors (a_1 = 65+, a_2 = 75+) in year y = 2018 in region r;

$w_{ai}^{y=2018,r}$ = weight share of seniors by age groups ai (a_1 = 65–74, a_2 = 75–84, a_3 = 85–94, a_4 = 95+) in y = 2018 in region r;

$a_{Svk,i}$ = expected proportion of age groups in residential facilities in Slovakia (a_{1svk1} = 0.196, a_{1svk2} = 0.445, a_{1svk3} = 0.296, a_{1svk4} = 0.063; a_{2svk1} = 0.10, a_{2svk2} = 0.48, a_{2svk3} = 0.33, a_{2svk4} = 0.09);

$PS_{ai}^{y=2018,r}$ = number of seniors in year y = 2018 in region r in age groups.

The second stage of the study incorporates the analysis of selected indicators obtained from the three models by multivariate statistical methods. The research further focuses on the delimitation of 'risky propositions' for regions that may be at risk of providing available residential care for the senior population in 2040. The selection of fundamental variables then differentiates the regions' risks in available social services. Table 1 provides an overview of the indicators used and calculation methods. The input data matrix contained information for the 72 regions (LAU1) and five selected indicators. The indicators were first normalised by the MIN-MAX method. Normalisation enables a combination of indicators with different units of measurement and different scales. The formula comprises: v_i is the normalised value of the indicator in the $<0,1>$ range; v_j is the indicator's value in a particular grid, and min_v and max_v are the minimum and maximum values of that indicator (Hendl, 2012). The calculation for the given type of indicators was used because all indicators were of the minimum type (5).

$$v'_j = \frac{v_j - min_v}{max_v - min_v} \qquad (5)$$

The input indicators for mutual linear dependence were tested in the next step before applying the factor analysis. Bartlett's and Kaiser–Meyer–Olkin (KMO) tests were used to test the relevance of the input variables for factor analysis. The significance of Bartlett's test ($p < 0.001$) and the KMO value (65+ = 0.68; 75+ = 0.67) support the adequacy of the factor analysis. The factors were extracted based on Principal Component Analysis (PCA) with Varimax rotation with Kaiser Normalisation. Obtaining principal components depends on the decomposition of the covariance matrix. Once the covariance matrix is determined (Nestorová Dická et al., 2019), eigenvalues are calculated, indicating the degree of total variance explanation represented by each component. Results show that the principal component with the highest value is more representative than the others. The principal component represents preferentially by all the variables mentioned above. The calculations were performed in the software of the PASW Statistics 18.0.0.

The loadings for each of the five indicators derived from the first principal component were then used as weighting criteria in an algebraic equation to calculate a factorial score for each region in Slovakia. The factor score represents a new dimension of the original indicators, which uses the factor weights of all the original features for the relevant common factor (Lubyová and Vojtková 2014). The PCA method has been used to estimate the factor matrix, from which two factors were extracted for both variants. Factors together explain up to 86% of the total variability of the input data for variant 65+, 84% for 75+. The results indicate that based on five indicators, at least two risk-security continuums exist, which in their way represent different levels of need for residential solution care. Loading scores of two factors were assigned to a two-by-two classification ranging from 'high risk' to 'low risk,' thus mapping a four-fold typology of districts (see Fig. 1). Adoption of this two-dimensional concept enables regional classification. Both factors allow to be used separately and together. The two-dimensional approach offers a direct method for monitoring changes between districts. Only regions at 'extreme risk' or 'extreme non-risk' along both factors should be considered the two extremes of the risk-security continuum spectrum.

4. Results of modelling demand for residential facilities for seniors through 2040

Changes in the reproductive behaviours of the population of Slovakia, an increased life expectancy, and shifts in the largest age groups compared to the post-war period, have created a situation with more elderly people in the population of Slovakia today than children under the age of 14. Population forecasts, such as Šprocha et al. (2019), now

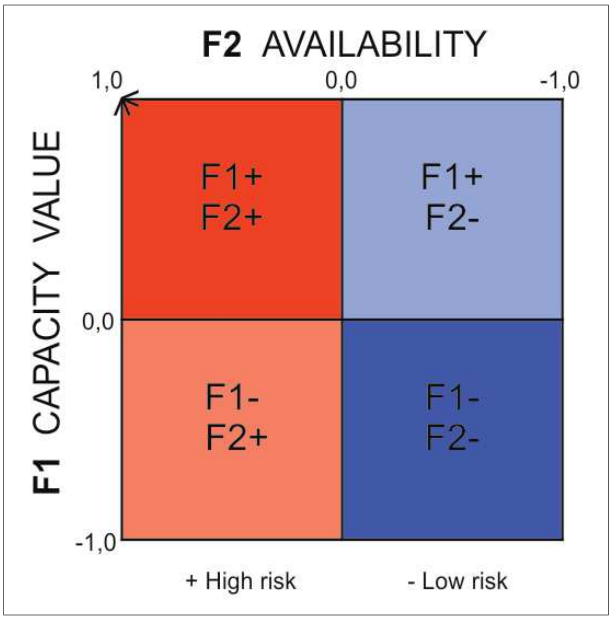


Fig. 1: Typification according to the intensity of the influence of risk factors
Sources: MLSAF SR (2018); SO SR (2018); Šprocha et al. (2019); authors' calculations

Indicator description	Design Calculation
Change in the demand of seniors for a bed in RF	$M_A^{y=2040,r} - M_A^{y=2018,r}$
Change in RF capacity	$M_B^{y=2040,r} - k^{y=2018,r}$
Change in RF capacity according to the age of the clients	$M_C^{y=2040,r} - k^{y=2018,r}$
Relative change in RF capacity according to the age of clients	$\frac{M_C^{y=2018,r}}{k^{y=2018,r}}$
The concentration of RF capacity per built-up area	$\frac{k^{y=2018,r}}{ZP^{y=2018,r}}$

Tab. 1: Indicators used for multidimensional statistical methods
Note: $P^{y=2040,r}$ = Population in year y = 2040 in region r; $ZP^{y=2018,r}$ = built-up area in km^2 in years y = 2018 in region r; RF = Residential Facilities

indicate a significant acceleration in the growth of the senior population in Slovakia. The persisting trend in increased life expectancy of both men and women in Slovakia has resulted in more people living to a superior age, i.e. people who are likely to be more dependent on social and health care. The "oldest-old" population (80+) has increased by more than 70% since the beginning of the millennium, and 2040 forecasts predict almost 2.5-fold further growth, where every 12th person will be over 80 (see Fig. 2). Similarly, the realised field survey of the representation of age categories showed high rates of service users for seniors over the age of 80 as high-potential clients of long-term care in the RF. The social sector is also responding to this development by continuously improving the availability of long-term care in RF (Fig. 3). In addition, Ludwigh Sintulova and Buzalova (2021) indicate that 2008 was the breakthrough year in developing social services in Slovakia. Act 448/2008 legislated new social service tasks to municipalities, regional stakeholders, and social services providers. It remains questionable, however, whether social support in Slovakia will be sufficient, considering current predictions of its increasing senior population.

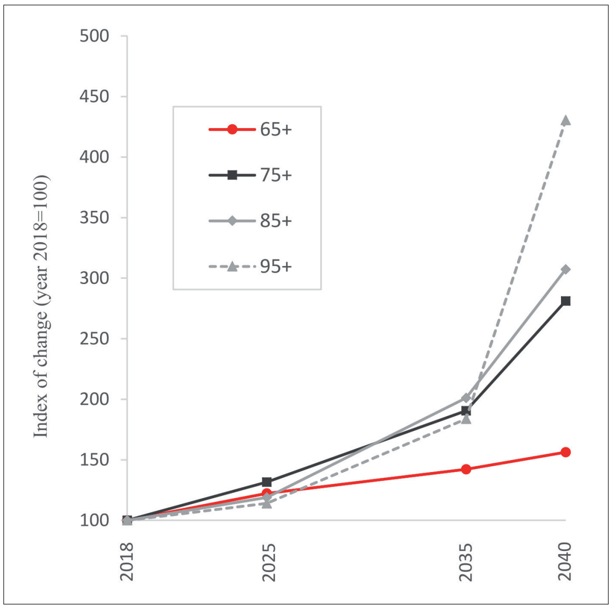


Fig. 2: Expected people in selected senior age categories, Slovakia, 2018–2040
Source: Šprocha et al. (2019); authors' elaboration

The implementation of the 2008 reform resulted in significant changes in the RF network and bed capacity (see Figs. 3–5). Kačerová et al. (2013) noticed that after 2009, the founders of the facilities adjusted the number of beds to the current needs - the number of applicants. The reduction of capacities in the regions of Slovakia affected the adoption of several measures:

1. The introduction of a care allowance for family members, which also solved the situation of rising unemployment during the financial crisis of 2008 and, at the same time, long-term unemployment of the elderly population;
2. Preference for informal care over formal residential social care within the maximum use of the efforts of the individuals and their families to solve the situation; and
3. Transfer of the competencies of social care for the seniors to municipalities that were not prepared in this regard, due to funding or qualified employees in the social care area.

The renewed increase in capacity was caused only by de-institutionalisation in the social services system, which significantly expanded the network of facilities, especially non-public providers, after 2011. In the case of Slovakia, de-institutionalisation started later than in other European welfare states, as part of a radical transformation from one social services model to another (Kubalčíková et al., 2017). The reforms aimed to improve the quality-of-care services, create sustainable financing mechanisms, and increase social inclusion.

Due to the implemented social care reform, which also allowed the non-governmental sector to enter the market for social service providers, the availability of long-term care for the senior population in Slovakia has gradually improved. Although these entities own 49% of current facilities, these have less capacity and provide care for only 39.9 % of seniors at 7,800 placements. Figure 4 shows an improvement of availability since 2015 so that numbers of seniors per bed have stabilised. This was influenced by gross (RF) capacity and an only slight increase in the senior population. In

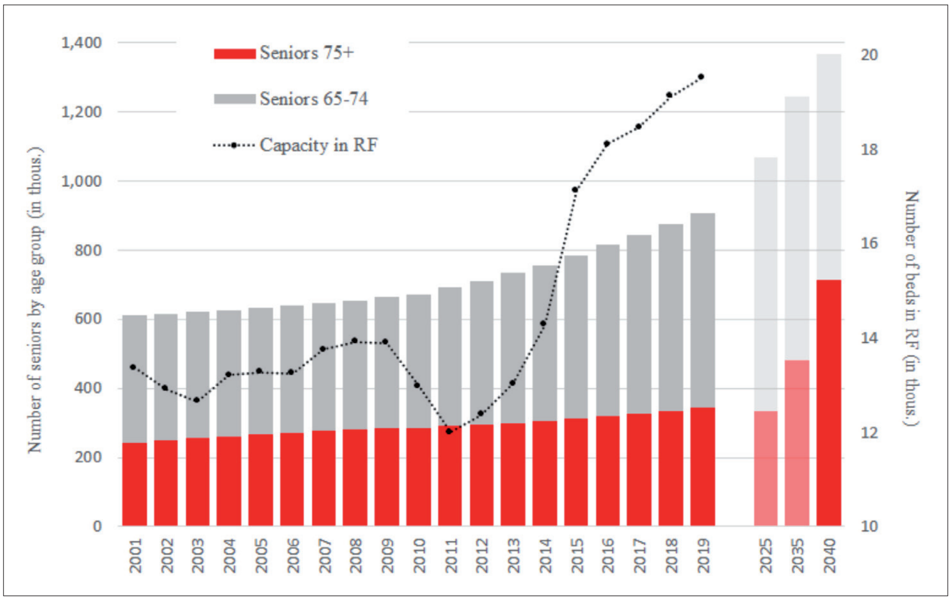


Fig. 3: Trend of seniors and capacity in residential facilities, Slovakia, 2001–2040
Source: SO SR, (2018); Šprocha et al. (2019); authors' elaboration

Slovakia, about 46 people aged 65+ are registered per one RF bed, 18 people are aged 75+. A similar development record in the indicator of amenities standards exists. Šídlo and Křesťanová (2018) base their indicator on data by the number of persons in need of help, their age, level of disability and non-separate, and therefore represent the recommended number of beds in RF per thousand people. For example, if there were 17 beds per 1,000 senior people over 65 years in 2011, today it is almost 22beds, equating to 57 beds per 1,000 people for 75+ seniors (see Fig. 5). In addition, SAO SR (2018) quotes an increasing number of pending applications each year. Although the situation

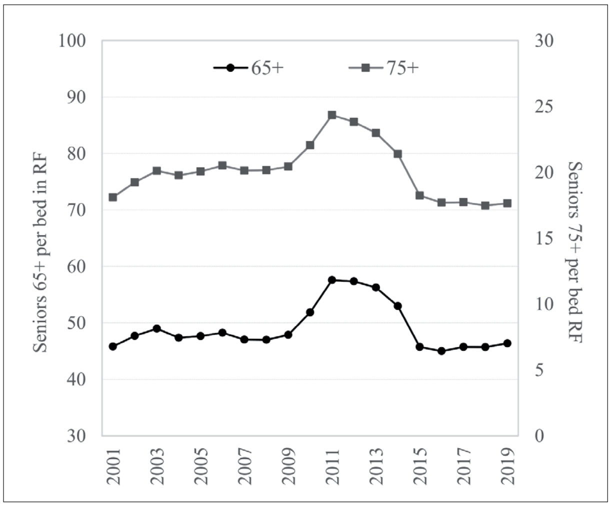


Fig. 4: Trend in the index of space availability, age 65+ and 75+, Slovakia, 2001–2019
Source: SO SR (2020); authors' elaboration

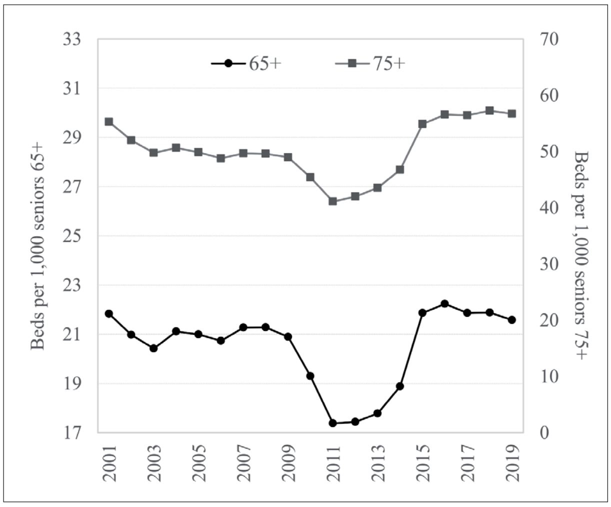


Fig. 5: Trend in amenities standards, age 65+ and 75+, Slovakia, 2001–2019
Source: SO SR (2020); authors' elaboration

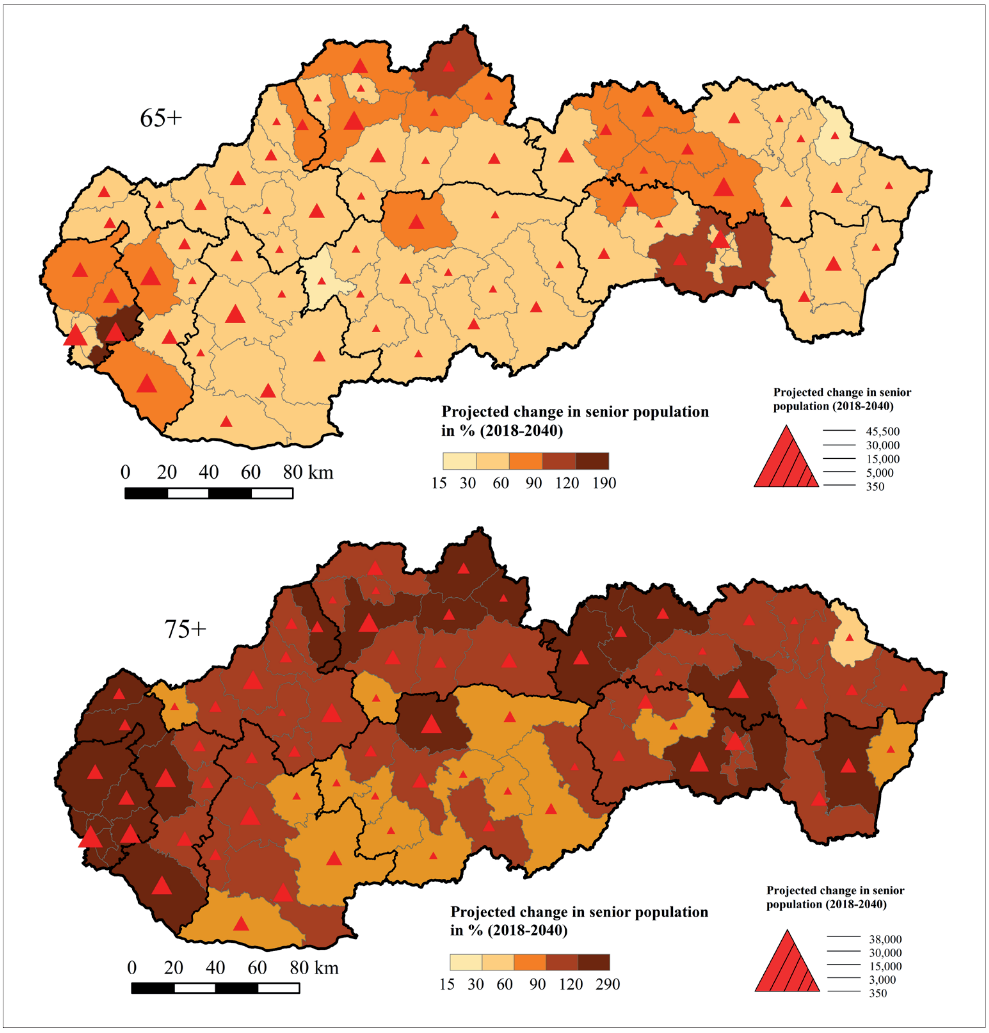


Fig. 6: Estimated population change of seniors in the regions of Slovakia, 2018–2040
Sources: SO SR (2018); Šprocha et al. (2019); authors' elaboration

has improved, it is still unsatisfactory, and it is necessary to consider expanding the RF network or supporting other forms of social care.

The model projections seek to estimate the Slovak capacity and availability of residential care in 2040. The models of Šídlová et al. (2016) indicate how regional capacities should change, taking the grown senior population into account, so that the input assumptions are preserved. The model projection calculations confirmed the changing availability of residential care due to the projected constant increase in the senior population (see Fig. 6). The proposed projections model is based on monitoring the two leading indicators. Model A works with the rate of seniors per bed, while the other models work on calculated estimated capacity.

Model A results emphasise the changing availability of social services with subsequent senior population development while maintaining current RF capacity in Slovak regions (see Fig. 7). Future demographic development predicts continued ageing processes and consequent deterioration in service availability, i.e. 25-person increase in the number of 65+ seniors per bed and a 19-person increase in the 75+ age group (see Fig. 8). These increases also suggest that there will be potentially 54% more seniors over 65 per bed and 95% over 75 than today.

The current and projected geographical differences in population ageing and senior population sizes are reflected in the emergence of significant differences in the availability of residential social services in Slovakia from a regional perspective (see Figs. 9 and 11). This availability is expected to deteriorate in most Slovak districts, with maintained current capacity. At the beginning of the projection, more than 120 seniors were registered per bed in the Sobrance, Tvrdošín, Bánovce n/B and Malacky districts. This set will increase from four to fourteen districts by 2040. A favourable situation, however, is expected only in six districts (Medzilaborce, Skalica, Komárno, Krupina, Galanta and Bardejov). The ratio of current capacity to seniors there is most balanced. In one particular case, the Senec district has the most significant senior increase from 48 registered in 2018 to almost 140 seniors for each bed at the end of the screening. The demographic development of the district has long been influenced by processes of suburbanisation (Novotný, 2016; Švéda et al., 2016; Švéda, 2011). The population is still relatively young, with a significant proportion of people born during the 1970s, and these will reach senior age by the end of the projection. A similar situation occurs in the 75+ category, where accessibility improves significantly because of the smaller population in this age group. Again, a particular case is the Senec

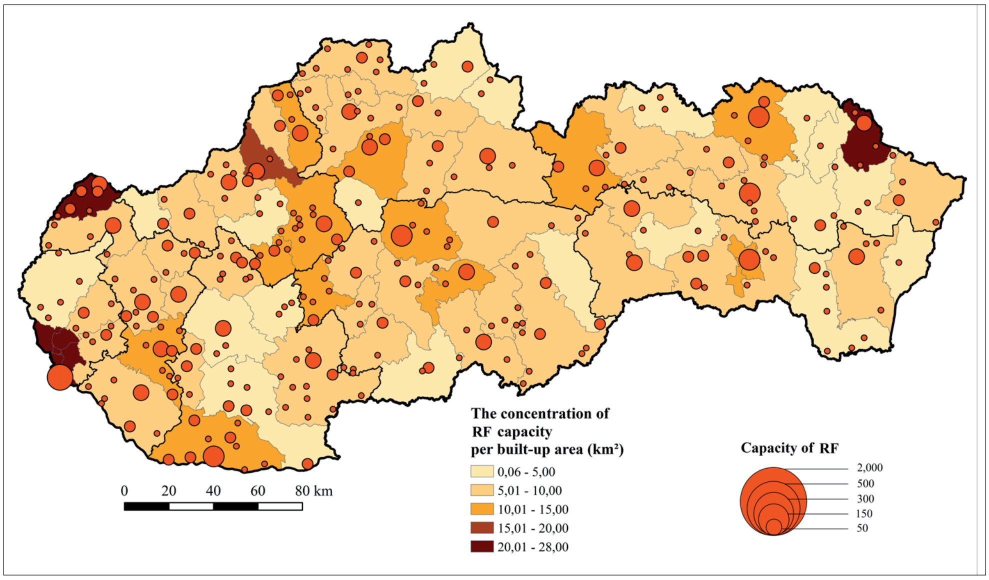


Fig. 7: The concentration of residential facilities capacity in Slovak regions
Source: MLSAF SR (2018); SO SR, (2018); authors' elaboration

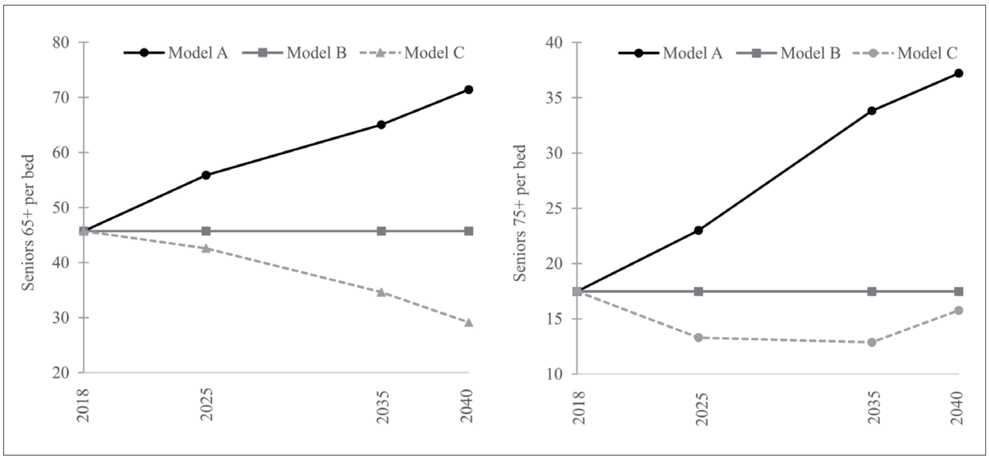


Fig. 8: Model estimates of the future number of seniors (65+ on the left, 75+ on the right) per one bed in residential facilities, Slovakia, 2018–2040. Sources: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' calculations

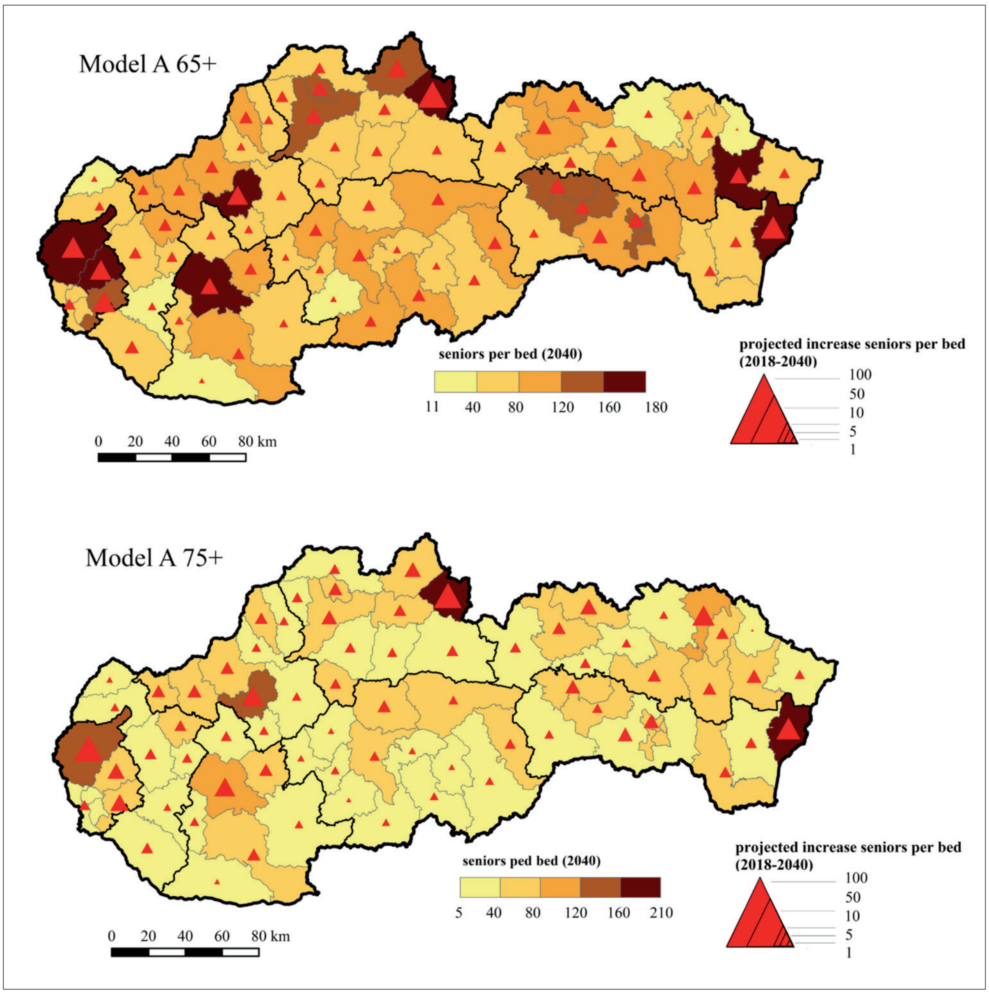


Fig. 9: Availability of residential social services for seniors from a regional perspective, Model A, Slovakia, 2018–2040
Source: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' elaboration

district and the Malacky and Svidník districts, where a more than 2.5-fold increase in the number of seniors over 75 years is expected per bed, because of this significant increase in the number of seniors at the end of the forecast.

Model B maintains the rate of RF service users throughout the entire projection period. Its results suggest an increase in capacity following the intensity of the growing senior population. At the current senior population and RF capacity ratio, the proportion of 65+ placed clients is approximately 2.2% and 5.7% for the 75+ group. Forecasts of the senior population are grown in Slovakia supports the model prediction of a reasonable rate of increase in RF beds. The size of the proposed capacity affects the following:

1. Growth in the senior population, excluding possible changes in the age structure of clients;
2. Changes in senior's health status;
3. Prolongation of the age of seniors without health limitations; and
4. Expanded forms of non-residential care.

The maintained rate of service users also results in the proposed capacity numbers, where the number of RF beds for the 65+ population would increase by an average of 490 beds per year and for 75+'s up to 980. In the first half of the projection, growth rates are more intense (see Fig. 10), which is interfered with by the forecasts of the expansion of the senior population. Regional estimates present the potential capacity at 10,800 higher for the case of65+ years older people, and up to 21,600 beds for the group 75+, at the end of the projection. Suggested capacity is increased by up to 56% and 113% than in 2018 for the 65+ and 75+ groups, respectively.

Constant rates of service users also vary significantly from region to region. Variability is influenced by the input assumptions of existing capacity and the number of seniors. The rate of service users in the areas varies from 3.3 to 102.0, with 75+ users comprising 7.8 – 227.7 per 1,000 seniors. Extreme values indicate an unequal level in the existing RF network and senior population size (see Appendix 3). For example, the Medzilaborce, and Sobrance extreme regions are affected by the uneven development of population ageing and consequent formation of RF networks. Therefore, the proposed potential capacities in the region depend on their constants (see Fig. 11). Model B proposes over double capacity in Senec, Námestovo, Košice-okolie and Pezinok districts by 2040. In the annual view, a high average annual increase of more than 15 beds per year was recorded for the following districts: Bratislava, Senec, Dunajska Streda, Galanta, Komarno and Skalica. Except for Senec, these already have a higher concentration of RF capacity. Still, the forecast increase in the senior population influences the recommended higher number of capacities in these regions.

Similar situations with different intensities occur in both 65+ and 75+ variants. While variant 65+ in Model B predicts over double RF capacity in four districts, this exists in the75+ group in up to 50 districts. An annual view further shows

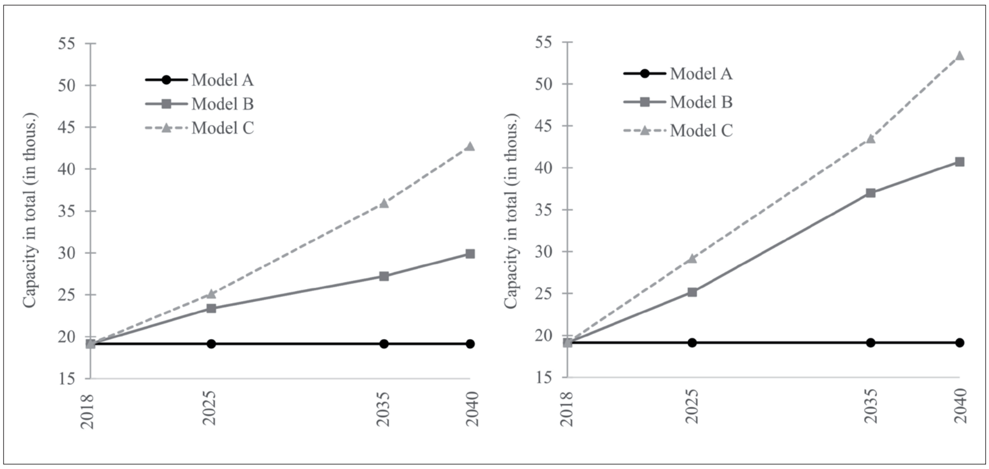


Fig. 10: Model estimates of trends in future potential residential facility capacities for seniors (65+ on the left, 75+ on the right), Slovakia, 2018–2040. Sources: SO SR, (2018); Šprocha et al., (2019); authors' elaboration

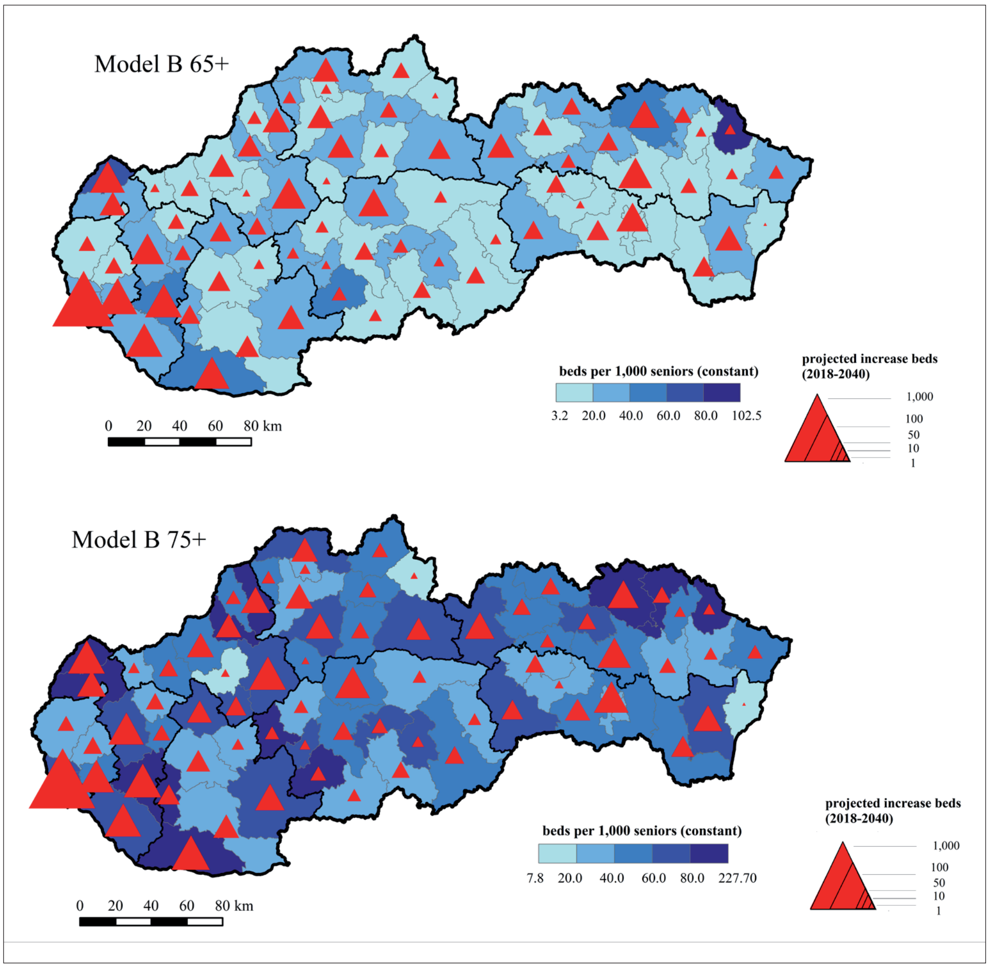


Fig. 11: Model estimates for trends in the future potential residential facility capacities for seniors, Model B, Slovakia, 2018–2040. Sources: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' elaboration

that option 65+ has high annual increases in six districts and that this is up to 24 districts for the 75+'s. They require an increase of over 300 beds during the projection period.

Model C is an improved projection that employs a constant ratio of clients to the number of seniors in the individual age groups. The potential capacity growth is even more significant and influential. Compared to model B, model C proposes an increase of places by more than 12,700 for 65+ seniors and 75+ (see Fig. 10). Since the rate of service users in Slovak RF differs by age groups and model C approximates the real estimated need, while maintaining the level of availability, this capacity should reach up to 42,700 places for variant 65+ and up to 53,400 for variant 75+, regarding the rising senior population in the highest age groups.

Figure 8 (above) shows the development trends for the A and C Models and depicts that the indicator of the number of seniors for one bed in Model C records the opposite trend to model A. This highlights a decrease in the number of seniors vying for one place in RF to below 30 in the 65+ group and 16 in the 75+'s. Šídlo and Křesťanová (2018)

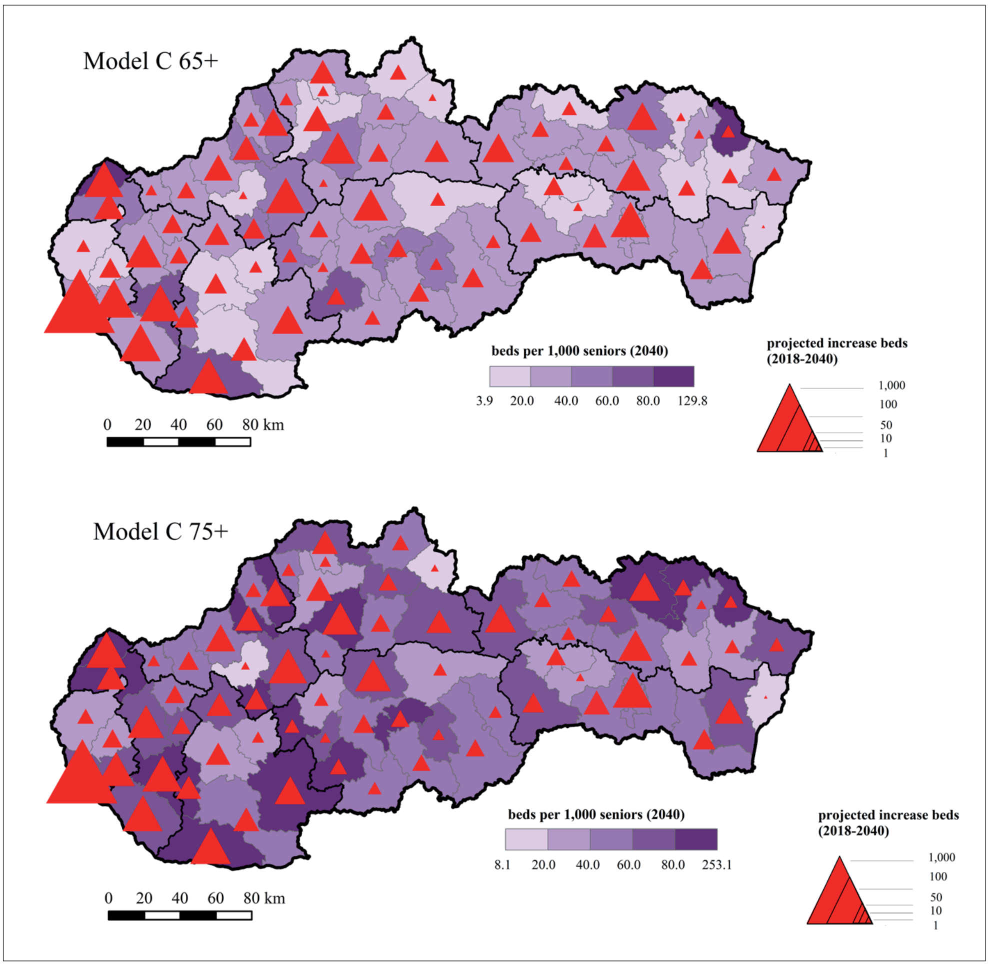


Fig. 12: Model estimates for trends in the future potential residential facility capacities for seniors, Model C, Slovakia, 2018–2040. Source: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' elaboration

support that this decrease indicates what changes will occur in the age structure of older people, with an increase in the proportion of seniors who will most need social services. The model's application aims to increase capacity to reduce the overall proportion of placed seniors, i.e. fewer seniors vying for a bed in the RF. Proposed values are again diverse from a regional viewpoint, and the availability in regions where the number of beds per senior is the lowest is unsatisfactory. The results reflect the input assumptions – set the weights/constants of service users according to age groups from the start of the projection - and therefore suggest an increase in capacity. Thus, the capacity increases in some regions should be even higher to meet at least the national the average number of beds for seniors (see Appendix 1).

Regional estimations of the three models were used as an input matrix in a factor analysis (see Appendix 2). Extraction of factors using PCA and calculation of eigenvalues showed that two main factors were obtained for the first (65+) and second (75+) variants. For 65+, the first factor accounted for 53% of the variance, and the second 33%. The combined factors account for over 86% of the variance in the original input data. For 75+, the first factor provided almost 54% of the variance, and the second 31%. The combined factors account for 84% of the variance in the original input data.

The factor loadings show two important groups regarding the availability of residential care for seniors in the future. The first factor is RF capacity because it is saturated with models B and C indicators. The second factor then indicates the availability of RF service because it is saturated with the results of model A. According to the two-by-two classification, factor scores (see Appendix 3) were used to typify regions regarding the future availability of residential long-term care. The terms were assigned two categories: "high risk" and "low risk". The spatial units are divided into four types of regions determining the future risk of availability of residential care (see Fig. 13).

Region types A, and B, have high positive values for the first RF capacity factor and a high level of capacity concentration. These regions will need a significant increase in available beds for the ongoing rise in the senior population, while maintaining the current rate of service users. The types differ in the level of availability of the social service while maintaining the current capacity of the RF and, at the same time, the intensity of increasing the proposed capacity. Type A has a high risk of worsening service availability while maintaining current capacity and needs significant capacity increases, with an almost 3-fold increase by 2040 while still maintaining today's level of service. As for type B, the availability of the current RF network will not significantly degrade, but maintaining the availability level requires an increase in the RF capacities regarding expanding to the senior population by the forecast.

Region types C, and D, have high negative values of the first RF capacity factor. Estimates of models B and C point to a less significant expansion of capacity, with forecasting just moderate expansion of the senior population while maintaining the current service users rate. It must be emphasised, however, that the lower proposed capacity

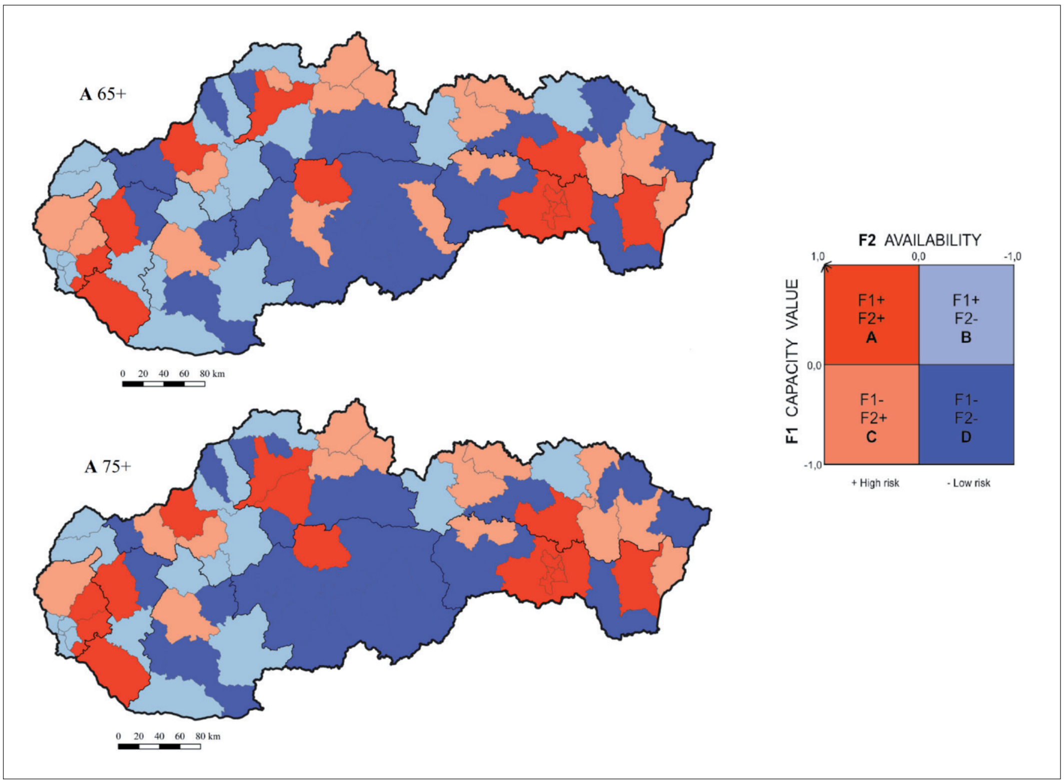


Fig. 13: Typification of regions Slovakia according to the intensity of the influence of risk factors
Source: MLSAF SR (2018); SO SR (2018); Šprocha et al., (2019); authors' elaboration

is associated with the current lower rate of service users for seniors. Like regional Types A and B, these differ in the level of service availability. Type D does not pose a significant worsening in the current availability. Despite the lower regional capacity concentration, this is due to a less important increasing senior population. The long-term effects of population ageing are a significant senior population already formed today in the region, and forecasts do not assume a future increasing senior group. In contrast, the C type with a very low-capacity concentration represents a high risk of worsening in availability while maintaining the current state of RF, with more than two-fold the projected increase in capacity in the region by 2040. In the region there is a need to improve the availability of social services for seniors significantly. The network will be unsatisfactory and require a significant increase in capacity to improve service availability.

All region types demonstrate the need to solve problems emanating from growth in the senior population and the availability of social services, but to varying degrees. The 'high risk' are types A and C because they show a significant increase in the senior population. There will be a significant worsening in social services availability unless capacity increases. In contrast, 'low risk' are types B and D. These regions have minor risks and require less problem-solving than other regions.

5. Discussion

In the short term, Slovakia will lose its status as a relatively 'young population' in the European Union states (Fihel and Okólski, 2019; Bartosovic et al., 2017; Káčerová and Ondačková, 2015; Šprocha and Ďurček, 2019). This is due to the rapid growth in the senior population, which will significantly exceed the child population. Šídlo et al. (2020) report that the expansion of the senior population in Slovakia is faster, for example, than in northern and western European countries. In addition, the SO SR (2019) records that 2018 was a breakthrough year in Slovak population ageing. The number and proportion of seniors exceeded the number and proportion of children for the first time in Slovakia's history. The number of seniors in 2040 is expected to increase the number recorded in 2018 by 56% and then by 75% by 2050.

This fact confirms the interest of many studies (e.g. Wang and Tsay, 2012; Tsutsui and Muramatsu, 2007; Fujisawa and Colombo, 2009) devoted to the growing demand for healthy, social, and family services for the seniors. Slovakia currently registers insufficiently secured residential long-term care, as the number of applicants increases each year (SAO SR, 2018). Krajňaková (2009) adds that the uncovered capacity needs for social service facilities are an objective consequence of the unfavourable state of health of the population of Slovakia.

The situation in Slovakia, however, is somewhat more favourable than for example in the Czech Republic. The existing Slovak RF network has 48 seniors for each place compared to the Czech number of 54 seniors (Šídlo and Křesťanová, 2018)[1]. There was a similar estimate of 71 Slovak seniors by 2040 compared to 76 in the Czech Republic, considering the current capacities in RF of the countries. Kačerová and Ondačková (2015) reported that these differences are related to the delayed onset of ageing

[1] Research in the Czech Republic (Šídlo and Křesťanová, 2018) is focused only on a selected type of facility for seniors: without beds, or Homes with a special regime for the Seniors. Research in Slovakia is similarly oriented, but in the data of individual facilities, there may be beds intended for a special regime.

processes typical of the more conservative countries such as Slovakia and Poland. Šídlo et al. (2020) obtained similar results in assessing population ageing from a retrospective and prospective perspective.

The regional results of the three model projections estimate different levels of residential care needs for seniors in 2040. There are significant differences between the regions of Slovakia, however, due to different levels of population ageing (Kačerová et al., 2012) and the uneven concentration of capacities RF in regions (Gavurova, 2016). This study identified regions with 'high risk' for the availability of residential care in 2040. These include both those with a high level of concentration beds in RF, and those with low levels such as Košice, Košice-Okolie, Senec, Dunajská Streda, Banská Bystrica, Sobrance, Tvrdošín, Humenné, Malacky, Bánovce n/B and Svidník. In addition, Krajňaková (2009) reported that regions with less intensive family and kinship relationships have more significant social service amenities, and areas with a high level of family solidarity and belonging have fewer amenities. This author emphasises that the following factors influence the unevenness in regional social services: level of urbanisation, age, qualifications, professional, the social structure of the population, the degree of implementation of traditional family care functions for the seniors, or sociological changes taking place in society (e.g. disintegration of multigenerational family coexistence). Šprocha and Ďurček (2019) consider that these regions will exhibit a higher rate of population ageing by the end of 2040. Regional differences in population ageing are also caused by long-term migration trends, especially younger inhabitants migrating to cities and suburbs. This is mainly influenced by the concentration of employment opportunities and locations with economic and social benefits (Kačerová et al., 2012). Novotny and Pregi (2019) confirmed that this selective migration considers age and educational level.

Regions of Slovakia identified at less risk in the study included Medzilaborce, Rožňava, Skalica, Poltár, Žarnovica and Banská Štiavnica. These districts have a suitable RF network because of more intense action population ageing processes (Bucher, 2012; Šprocha and Ďurček, 2019). In these results, one can also observe a more favourable state in the capacities of RF in regions where there is preferred home care to institutional care, due to higher unemployment of people over the age of 50. Later, the restatement of the law and its transformation led to the modernisation of social services, new forms of institutional care services, including home care, and home care is being replaced by care by the residential sector for the seniors (Ludvigh Cintulová and Buzalová, 2021). The model projections enable an individual approach to each region and proposed opportunities for the further development of social services for seniors in various forms, so that the supply is sufficient and suitable for the population ageing level.

The research on a possible load of RF for seniors in the regions of Slovakia also has several limits or restrictions. The age structure of RF clients may change in the future. Despite the existing evidence of prolongation of the healthy period after the age of 65 of life in Slovakia (OECD, 2020), it is difficult to predict the future demand for social care due to the age of the senior. The application of two-variant modelling of care availability also follows from the above. Variant 75+ is determined by the prolonged age of a self-sufficient senior, i.e. without the need for social care. Variant 65+ determines the possibility of a braking or reversal of processes related to the extension of the age of a senior without health restrictions caused by, e.g. the current spread of Covid19, which the population of the elderly is most affected by (Šprocha, 2021).

The use of current rates of service users for the seniors in the regions of Slovakia also has its limits. The research points to an increase or reduction of residential facilities' capacity for the seniors about maintaining the current rate of service users. At the same time, we do not know whether the existing network of RF in the regions is satisfactory. Suppose the national values of the rate of service users (see Fig. 4) represent the minimum standard. In that case, more than one-third of the districts of Slovakia today have insufficient capacity in RF concerning the population of seniors. Model projections of future availability assumes maintaining the current situation in the regions of Slovakia. Still, there is no guarantee that the current capacity in the RF is sufficient. An example is the districts of Tvrdošín and Sobrance (Fig. 9), where the number of beds in the facilities is meagre. Kačerová et al. (2013) similarly pointed to the under-designed nature of these districts of Slovakia in the availability of residential social services, which was already registered in 2010. According to these authors, the impact of the different demand for residential services in Slovakia is determined by the factor of population religiosity and the resulting stronger pro-family behaviours. At the same time, a significant increase in the senior population is expected in the future. Demographic forecasts point to elderly seniors (80-year-olds) who usually participate in higher use of residential facilities and, therefore, the need for further development. Typifying districts by the risk of availability to social care consider these limits.

There are also some restrictions to using districts (LAU1) as spatial units. The choice of research units resulted from the authorities' Self-governing Region guidelines for placing a senior in a facility as close as possible to their place of residence. Field research (additionally a survey via local web portals: Self-governing Region) indicates that more than 90% of clients come from the facility's district. Kacerova et al. (2021) add that seniors need to have a suitable facility with a suitable form of service as close as possible to their place of residence. It can be perceived that demand and supply meet in the market through the way of optimisation decisions of subjects. The interest is the smallest possible distance between the place of residence and the residential facility, also about family ties and the financial demands of the service. The possible migration of seniors within the districts of Slovakia is low if it occurs due to the lack of RF beds in the region.

Modelling care availability is also limited by uncertainty towards the family, i.e. informal care (Hatar, 2012). The second demographic transition caused severe changes in the population of Slovakia (e.g. a significant increase in one-person households or cohabitation, a decrease in the economically productive population), which are rather a barrier to further expansion of informal care in the form of intergenerational solidarity. Despite the mentioned limitations, we consider the research results relevant to the current and future state of the client service rate concerning the ongoing processes of expansion of the senior population, as well as the state of the existing network of facilities for seniors in the regions of Slovakia.

Our study results do not relate to some strict adherence to the proposed regional opportunities; instead, they indicate risk in the availability of social services and the urgency of a timely resolution to the situation. Residential care is just one form of social care for seniors. One of the possibilities for helping seniors is developing and supporting active ageing. In addition, Kaščáková and Martinkovičová (2019) support our consideration that older adults in Slovakia are ageing 'in the spirit of ageing well'. These authors add that the following factors are important: high senior subjective well-being; promoting independence; creating community programs to improve and maintain physical activity; and supporting education. Finally, Slovakia's Active Aging Index has gradually increased (UNECE, 2019). Slovakia, however, ranks only 7th from the bottom on the European Union countries list. The state is improving its position, and it is four positions higher than in 2014 (Bartosovic et al., 2017). The onset of these trends, together with the improvement of the health status (Health Outlook: Europe, 2020) or quality of life for seniors (e.g. Madziková et al., 2015; Soósová, 2016; Rišová and Pouš, 2018), has a significant impact in solving the risks in residential care availability.

6. Conclusions

Modelling the phenomena that await us soon is extremely important. This study focuses on long-term residential social care requirements, and the model projections are significantly influenced by forecasted population ageing. Moreover, from the economic to the social factors, the public sector should be able to derive much from such predictions. Demographic ageing is a current challenge for public policy and requires searching for solutions to ensure the quality of social care for the elderly in every society. For this reason, there is pressure on the political system to ensure sufficient availability of social services close to where people need services due to their age or health status. The social support network for the seniors must be continuously adapted to the demands of society. At the same time, the residential sector supports need to be permanently planned (Matei et al., 2018) from a temporal and spatial perspective, so that they cope with ageing dynamics and the spatial distribution of the clusters of senior people.

The research pointed to an impending regional shortage of opportunities for residential long-term care for seniors in the future. Therefore, it is necessary to ensure adequate development of facilities and social services, for cases, according to Krajňaková (2009), where the provision of other types of social services is impossible or insufficient, whether concerning the health status, age, or social needs of the citizens eligible. The government authorities should look for ways to cope with a changing population structure, as increasing life expectancy is associated with higher demand for residential care for the seniors and spatial differences in the supply of care for the seniors. The state is fully aware of the current situation. It is tackling the sustainability of social assistance, primarily by supporting home care services to prevent the placement of seniors in residential facilities and providing financial support for the construction, procurement, or renovation of residential facilities. Concurrent with the expansion of residential facilities for an ageing population, the sustainability concept is also gaining more prominence in senior care studies (Yuan et al., 2019). Economic, environmental, and social sustainability play an important role.

Field findings in selected residential facilities also indicated full occupancy, with different waiting lists for placement in the facility. In response to the urgent need for more age-specific spaces, these facilities for the elderly are already experiencing a significant increase in number and capacity in Slovakia. From a regional perspective, the supply of residential social services is uneven and insufficient. The unstable political and economic situation during the Covid-19 pandemic is hindering the further development of social services. The current legislative changes in Slovakia contribute to creating different conditions for social services providers - state and non-state. In addition, the future financing of social services is unclear and unstable, which leads to stagnation in the development of residential facilities for seniors in Slovakia.

Acknowledgement

This research was supported by the Scientific Grant Agency of the Ministry of Education, science, research and sport of the Slovak Republic and the Slovak Academy of Sciences: Grant Number VEGA 1/0514/21 – "Spatial redistribution of human capital as an indicator of the formation of the regional system in Slovakia".

References:

BARTOSOVIC, I., ZACHAROVA, E., ZRUBAKOVA, K., COSTELLO, M. M. (2017): Demographic Characteristics of Population Ageing in Slovakia. Clinical Social Work and Health Intervention, 8(3): 7–14.

BEARD, J. R., OFFICER, A., DE CARVALHO, I. A., SADANA, R., POT, A. M., MICHEL, J. P., LLOYD-SHERLOCK, P., ... CHATTERJI, S. (2016): The World report on ageing and health: a policy framework for healthy ageing. The Lancet, 387(10033): 2145–2154.

BENÍTEZ-AURIOLES, B. (2018): The implications of demographic and economic projections on public pension spending in the European Union. Journal of International and Comparative Social Policy, 34(1): 19–39.

BERG, A. (2021): What is the difference between a Care Home and a Nursing Home? [online]. [cit. 18.09.2021]. Available at: https://www.carehome.co.uk/advice/what-is-the-difference-between-a-care-home-and-a-nursing-home

BEZÁK, A. (1996): Reflexie nad novým administratívnym členením Slovenskej republiky. Geografické informácie, 4: 7–9.

BEZÁK, A. (1997): Priestorová organizácia spoločnosti a územno-správne členenie štátu. Geografické štúdie, 3: 6–13.

BEZÁK, A. (2001): O regionálnych trhoch práce, nových krajoch a tokoch nezamestnaných. Geografický časopis, 53(4): 295–305.

BEZÁK, A. (2011): Redistribúcia obyvateľstva vo funkčných mestských regiónoch na Slovensku v období 1991–2010. Geographia Cassoviensis, 5(2): 5–16.

BLEHA, B., MÉSZÁROS, J., PILINSKÁ, V., ŠPROCHA, B., VAŇO, B. (2020): Analýza demografického vývoja oblastí a obcí podľa štatútu a veľkosti v Slovenskej republike. INFOSTAT Bratislava, Výskumné demografické centrum, Prírodovedecká fakulta UK, Centrum spoločenských a psychologických vied SAV.

BLEHA, B., ŠPROCHA, B., VAŇO, B. (2018): Prognóza obyvateľov Slovenska do roku 2060. Bratislava, INFOSTAT Inštitút informatiky a štatistiky – Výskumné demografické centrum.

BUCHER, S. (2012): Aspects of the phenomenon of demographic population ageing in Czechia and Slovakia: time and regional dimensions. Human Geographies-Journal of Studies in Human Geography, 6(1): 25–33.

CARR, S. (2007): Participation, power, conflict and change: Theorising dynamics of service user participation in the social care system of England and Wales. Critical social policy, 27(2): 266–276.

CHAPPELL, N. L., DLITT, B. H., HOLLANDER, M. J., MILLER, J. A., McWILLIAM, C. (2004): Comparative costs of home care and residential care. The Gerontologist, 44(3): 389–400.

DEL DUCA, G. F., SILVA, S. G. D., THUMÉ, E., SANTOS, I. S., HALLAL, P. C. (2012): Predictive factors for institutionalization of the elderly: a case-control study. Revista de saúde pública, 46: 147–153.

EUROSTAT (2021): Population projections at national level [online]. [cit. 13.09.2021]. Available at: https://ec.europa.eu/eurostat/web/population-demography/population-projections

FENG, Z., LIU, C., GUAN, X., MOR, V. (2012): China's rapidly aging population creates policy challenges in shaping a viable long-term care system. Health Affairs, 31(12): 2764–2773.

FIHEL, A., OKÓLSKI, M. (2019): Diminution de la population dans les pays anciennement communistes de l'Union européenne. Population Societes, 567(6): 1–4.

FUJISAWA, R., COLOMBO, F. (2009): The Long-Term Care Workforce: Overview and Strategies to Adapt Supply to a Growing Demand. OECD Health Working Papers, No. 44, Paris, OECD Publishing.

HATÁR, C. (2012): Domáca verzus inštitucionálna starostlivosť o nesebestačných seniorom alebo o medzigeneračnej solidarite inak. In: Balogová, D. [ed.]: Medzigeneračné mosty–vstupujeme do roka medzigeneračnej solidarity: zborník príspevkov z konferencie s medzinárodnou účasťou 10.11.2011 v Prešove (pp. 34–44), Prešov, FF PU.

HALFON, N., FORREST, C. B. (2018): The emerging theoretical framework of life course health development. In: Halfon, N., Forrest, C. B., Lerner, R., Faustman, E. [eds.]: Handbook of Life Course Health Development (pp. 19–43). Cham, Springer.

HENDL, J. (2012): Přehled statistických metod: analýza a metaanalýza dat. Praha, Portál.

JAGGER, C., GILLIES, C., MOSCONE, F., CAMBOIS, E., VAN OYEN, H., NUSSELDER, W., ROBINE, J. M. (2008): Inequalities in healthy life years in the 25 countries of the European Union in 2005: a cross-national meta-regression analysis. The Lancet, 372(9656): 2124–2131.

KÁČEROVÁ, M., ONDAČKOVÁ, J. (2015): The process of population ageing in countries of the Visegrad Group (V4). Erdkunde, 69(1): 49–68.

KÁČEROVÁ, M., ONDAČKOVÁ, J., MLÁDEK, J. (2012): A comparison of population ageing in the Czech Republic and the Slovak Republic based on generation support and exchange. Moravian Geographical Reports, 20(4): 26–38.

KÁČEROVÁ, M., ONDAČKOVÁ, J., MLÁDEK, J. (2013): Sociálne služby pre seniorov, typy, veľkosť a priestorová diferencovanosť–komparácia Českej republiky a Slovenskej republiky. Regionální studia, 1(7): 51–66.

KÁČEROVÁ, M., ONDOŠ, S., MILÁČKOVÁ, M. (2021): Regionálne nerovnosti v zdravotnej a sociálnej starostlivosti o seniorov na Slovensku. Geographia Cassoviensis, 15(2): 135–149.

KAŠČÁKOVÁ, A., MARTINKOVIČOVÁ, M. (2019): Active ageing in Slovakia. Problemy Polityki Społecznej. Studia i Dyskusje, 45(2): 47–67.

KLUGE, F. A., GOLDSTEIN, J. R., VOGT, T. C. (2019): Transfers in an aging European Union. The Journal of the Economics of Ageing, 13: 45–54.

KRAJŇÁKOVÁ, E. (2009): Realizácia sociálnych služieb v podmienkach Slovenska. Scientific papers of the University of Pardubice. Series D: Faculty of Economics and Administration, 14: 118–133.

KUBALČÍKOVÁ, K., SZÜDI, G., SZÜDI, J., HAVLÍKOVÁ, J. (2017): The de-institutionalisation of care for older people in the Czech Republic and Slovakia: national strategies and local outcomes. In: Martinelli, F., Anttonet, A., Mätzke, M. [eds.]: Changes, Social services disrupted. Challenges and Policy Implications for Europe in Times of Austerity (pp. 239–258). Edward Elgar Publishing.

LESTAGE, C., DUBUC, N., BRAVO, G. (2008): Identifying characteristics of residential care facilities relevant to the placement process of seniors. Journal of the American Medical Directors Association, 9(2): 95–101.

LI, J., HAN, X., ZHANG, X., WANG, S. (2019): Spatiotemporal evolution of global population ageing from 1960 to 2017. BMC public health, 19(127): 1–15.

LIM, W. W. X., SULAIMAN, N., BALDRY, D. (2013): A conceptual framework for understanding the social care facilities management audit (SCFMA) at the residential care home for the elderly (RCHFE) in Malaysia. In: Proceedings of the International Conference on Management, Economics and Finance (pp. 112–140). Hotel Novotel lBorneo, Kota Kinabalu, Sabah, Malaysia.

LIN, M. H., CHOU, M. Y., LIANG, C. K., PENG, L. N., CHEN, L. K. (2010): Population aging and its impacts: strategies of the health-care system in Taipei. Ageing research reviews, 9: 23–27.

LUBYOVÁ, M.; VOJTKOVÁ, M. (2014): Analysis of the degree of the attractiveness of national economies for foreign investors in the new globalized environment. Journal of Economics, 62(6): 557–578.

LUDVIGH CINTULOVÁ, L., BUZALOVÁ, S. (2021): Development of senior social services in the process of transformation and decentralisation and its present day forms in Slovakia. Kontakt, 23(2): 111–119.

LUKÁČOVÁ, N., NOVOTNÁ, A. (2020): Social Care for Seniors in Residential Facilities. In: McGreevy, M., Rita R. [eds.]: CER Comparative European Research 2020 – Proceedings/Research Track of the 14th Biannual, October 26–28, 2020 (pp. 200–204). London.

MADZIKOVA, A., MITRIKOVA, J., SENKOVA, A. (2015): Quality of life of seniors in the context of population ageing in Slovakia. Economic Annals-XXI, 7–8(1): 109–112.

MAGNUS, G. (2009): The age of ageing. Singapore, John Wiley.

MATEI, E., SAGHIN, D., DUMITRACHE, L., NAE, M. (2018): Multidimensional Approach on Sustainability of Ageing in Romanian Residential Care Centres for Elders. Sustainability, 10(9): 3336.

MLSAF SR, (2018): Central Register of Social Service Providers. Bratislava, Ministry of Labour, Social Affairs and Family of the Slovak Republic.

MUNYISIA EN, YU P, HAILEY D. (2011): How nursing staff spend their time on activities in a nursing home: an observational study. Journal of Advanced Nursing, 67(9): 1908–1917.

NESTOROVÁ DICKÁ, J. (2021): Demographic Changes in Slovak Roma Communities in the New Millennium. Sustainability, 13(7): 3735.

NESTOROVÁ DICKÁ, J., GESSERT, A., SNINČÁK, I. (2019): Rural and non-rural municipalities in the Slovak Republic. Journal of Maps, 15(1): 84–93.

NEWTON, J. N. (2021): Trends in health expectancies across Europe: Countries that are achieving compression of morbidity and those that are not. The Lancet Regional Health-Europe, 3: 100078.

NIKMAT, A. W., HAWTHORNE, G., AL-MASHOOR, S. H. (2015): The comparison of quality of life among people with mild dementia in nursing home and home care – a preliminary report. Dementia, 14(1): 114–125.

NOVOTNÝ, L. (2011): Funkčné mestské regióny najväčších slovenských miest v modeloch urbánneho vývoja. Geographia Cassoviensis, 5(2): 93–102.

NOVOTNÝ, L. (2012): Migrácia a prirodzený pohyb ako komponenty rastu obyvateľstva vo funkčnom mestskom regióne Košice. Geographia Cassoviensis, 6(2): 152–164.

NOVOTNÝ, L. (2016): Urban development and migration processes in the urban region of Bratislava from the post-socialist transformation until the global economic crisis. Urban Geography, 37(7): 1009–1029.

OECD/EUROPEAN UNION (2020): Health at a Glance: Europe 2020: State of Health in the EU Cycle. Paris, OECD Publishing.

PHILLIPS, D. R., FENG, Z. (2017): Global ageing. In: Skinner, M. W., Andrews, G. J., Cutchin, M. P. [eds.]: Geographical gerontology – Perspectives, Concepts, Approaches (pp. 93–109). Routledge.

PREGI, L., NOVOTNÝ, L. (2019): Selective migration of population in functional urban regions of Slovakia. Journal of Maps, 15(1): 94–102.

RECHEL, B., GRUNDY, E., ROBINE, J. M., CYLUS, J., MACKENBACH, J. P., KNAI, C., MCKEE, M. (2013): Ageing in the European union. The Lancet, 381(9874): 1312–1322.

REPKOVÁ, K., BRICHTOVÁ, L. (2011): Sociálna ochrana starších osôb a osôb so zdravotným postihnutím – aktuálny vývoj. Bratislava, EPOS.

RIŠOVÁ, K., POUŠ, R. (2018): Urban facilities in the quality of life research: a case study of Banská Bystrica city (Central Slovakia). Geografický časopis, 59(2): 159–179.

RUDNICKA, E., NAPIERAŁA, P., PODFIGURNA, A., MĘCZEKALSKI, B., SMOLARCZYK, R., GRYMOWICZ, M. (2020): The World Health Organization (WHO) approach to healthy ageing. Maturitas, 139: 6–11.

SANTOS, J. V., VIANA, J., DEVLEESSCHAUWER, B., HAAGSMA, J. A., SANTOS, C. C., RICCIARDI, W., FREITAS, A.(2021): Health expectancies in the European Union: Same concept, different methods, different results. Journal of epidemiology and Community Health, 75: 764–771.

SOÓSOVÁ, M. S. (2016): Determinants of quality of life in the elderly. Central European Journal of Nursing Midwifery, 7(3): 484–93.

SO SR (2019): Annual registration of population. Bratislava, Statistic Office of Slovak Republic.

SUPREME AUDIT OFFICE OF THE SLOVAK REPUBLIC (SAO SR) (2018): Final Report – Social services for seniors [online]. [cit. 04.05.2021]. Available at: https://www.nku.gov.sk/sk/medialne-vystupy/-/document_library_display/SgVA4fbLew3a/view/265201

SZEBEHELY, M., TRYDEGARD, G. B. (2011): Home care for older people in Sweden: A universal model in transition. Health & Social Care in the Community, 20(3): 300–309.

SZÜDI, G., KOVÁČOVÁ, J., KONEČNÝ, S. (2016): Transformation of social care services for the elderly in Slovakia. Journal of Social Service Research, 42(2): 199–217.

ŠÍDLO, L., KŘESŤANOVÁ, J. (2018): Kdo se postará? Domovy pro seniory v Česku v kontextu demografického stárnutí. Demografie, 60(3): 248–265.

ŠÍDLOVÁ KUNSTOVÁ, N., ŠÍDLO, L. (2016): The future development of elderly care home capacity in South Bohemia. Kontakt, 18(2): e103-e111.

ŠIDLO, L., ŠPROCHA, B., ĎURČEK, P. (2020): A retrospective and prospective view of current and future population ageing in the European Union 28 countries. Moravian Geographical Reports, 28(3): 187–207.

ŠPROCHA, B., BLEHA, B. (2018): Does Socio-Spatial Segregation Matter?'Islands' of High Romany Fertility in Slovakia. Tijdschrift voor economische en sociale geografie, 109(2): 239–255.

ŠPROCHA, B., VAŇO, B., BLEHA, B. (2019): Kraje a okresy v demografickej perspektíve: Populačná prognóza do roku 2040. Bratislava, INFOSTAT – Výskumné demografické centrum.

ŠPROCHA, B., ĎURČEK, P. (2019): Starnutie populácie Slovenska v čase a priestore. Bratislava, INFOSTAT Inštitút informatiky a štatistiky – Výskumné demografické centrum.

ŠVEDA, M. (2011): Časové a priestorové aspekty bytovej výstavby v zázemí Bratislavy v kontexte suburbanizácie. Urbanizmus a územní rozvoj, 14(3): 13–22.

ŠVEDA, M., MADAJOVÁ, M., PODOLÁK, P. (2016): Behind the differentiation of suburban development in the hinterland of Bratislava, Slovakia. Czech Sociological Review, 52(6): 893–925.

TEDIOSI, F., GABRIELE, S. (2010): The Long Term Care System for the Elderly in Italy. ENEPRI Research Report No. 80 [online]. [cit. 03.09.2021] Available at: http://www.ancien-longtermcare.eu/sites/default/files/ENEPRI%20_ANCIEN_%20RR%20No%2080%20Italy%20edited%20final.pdf

TSUTSUI, T., MURAMATSU, N. (2007). Japan's universal long-term care system reform of 2005: containing costs and realising a vision. Journal of the American Geriatrics Society, 55(9): 1458–1463.

UNECE/EUROPEAN COMMISSION (2019): Active Ageing Index 2018: Analytical Report [onine]. [cit. 28.10.2021]. Available at: https://unece.org/population/active-ageing-index

UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, POPULATION DIVISION (2019): World Population Prospects: The 2019 Revision (Medium variant).

VAŇKOVÁ, I., VAVREK, R. (2021): Evaluation of local accessibility of homes for seniors using multi-criteria approach–Evidence from the Czech Republic. Health & Social Care in the Community, 29(5): e21-e32.

VITORINO, L. M., PASKULIN, L. M. G., VIANNA, L. A. C. (2013): Quality of life of seniors living in the community and in long term care facilities: a comparative study. Revista latino-americana de enfermagem, 21(SPE): 3–11.

WANG, H. H., TSAY, S. F. (2012): Elderly and long-term care trends and policy in Taiwan: Challenges and opportunities for health care professionals. The Kaohsiung journal of medical sciences, 28(9): 465–469.

WELSH, C. E., MATTHEWS, F. E., JAGGER, C. (2021): Trends in life expectancy and healthy life years at birth and age 65 in the UK, 2008–2016, and other countries of the EU28: An observational cross-sectional study. The Lancet Regional Health-Europe, 2: 100023.

WOO, J. (2018): Challenges of population ageing: putting frailty as a cornerstone of health and social care systems. European Geriatric Medicine, 9: 273–276.

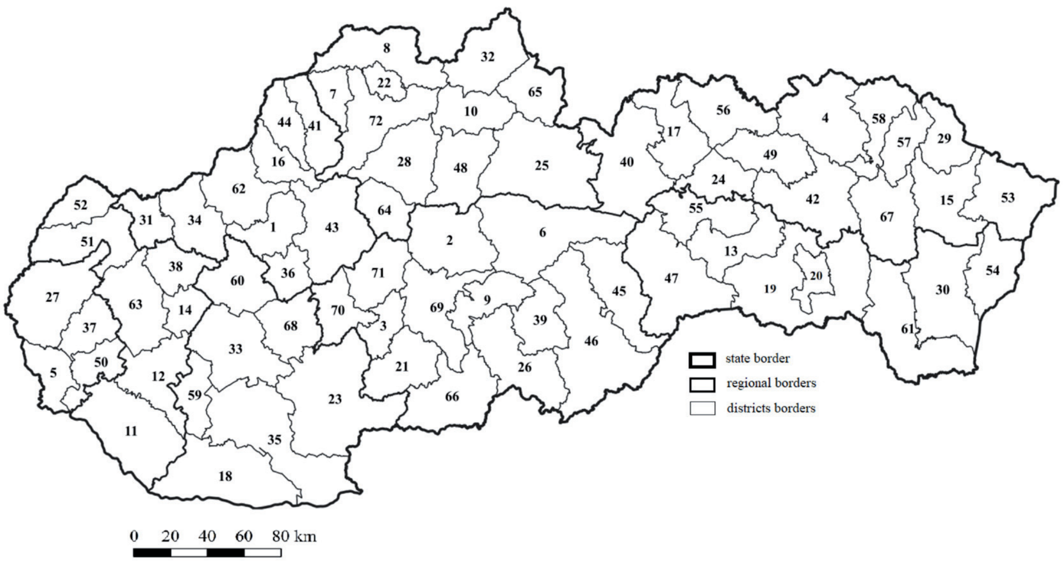
YUAN, J., LI, L., WANG, E., SKIBNIEWSKI, M. J. (2019): Examining sustainability indicators of space management in elderly Facilities—a case study in China. Journal of cleaner production, 208: 144–159.

ZAINOL, R., PETTIT, C. J. (2016): Elderly and community health care facilities: A spatial analysis. Planning Malaysia, 5: 49–64.

Please cite this article as:

NESTOROVÁ DICKÁ, J., GUROVÁ, P. (2022): The sustainability of social care in Slovakia: Modelling the existing network of residential social facilities for future senior populations. Moravian Geographical Reports, 30(2): 66–85. doi: https://doi.org/10.2478/mgr-2022-0005

Appendices



Appendix 1: Administrative divisions of Slovakia
Sources: Ministry of Interior of the Slovak Republic: NC of SR no. 221/1996 C. l. on the territorial and administrative organization of the Slovak Republic

Districts of Slovakia (LAU1)	Variant 65+		Variant 75+		Districts of Slovakia (LAU1)	Variant 65+		Variant 75+	
	F1	F2	F1	F2		F1	F2	F1	F2
Bánovce n/B	– 1.1	1.1	– 1.0	1.2	Pezinok	0.0	2.2	0.1	1.7
Banská Bystrica	1.0	0.2	1.2	0.5	Piešťany	– 0.4	– 0.1	– 0.3	– 0.1
Banská Štiavnica	– 0.7	– 0.9	– 0.7	– 0.8	Poltár	– 0.6	– 1.2	– 0.7	– 1.3
Bardejov	0.7	– 0.7	0.6	– 0.7	Poprad	0.6	– 0.1	0.7	0.0
Bratislava I–V	5.5	– 0.3	5.7	– 0.2	Považská Bystrica	0.8	– 0.4	0.7	– 0.4
Brezno	– 0.8	– 0.5	– 0.8	– 0.8	Prešov	0.8	0.4	0.7	0.3
Bytča	– 0.5	– 0.2	– 0.5	– 0.3	Prievidza	1.3	– 0.6	1.3	– 0.5
Čadca	0.2	– 0.2	0.2	– 0.2	Púchov	– 0.6	0.0	– 0.5	0.0
Detva	– 0.2	– 1.0	– 0.2	– 0.9	Revúca	– 0.7	0.1	– 0.7	– 0.1
Dolný Kubín	– 0.3	0.2	– 0.2	0.3	Rimavská Sobota	– 0.5	– 0.4	– 0.6	– 0.6
Dunajská Streda	1.4	1.1	1.3	1.0	Rožňava	– 0.3	– 0.5	– 0.3	– 0.5
Galanta	1.4	– 0.3	1.4	– 0.3	Ružomberok	– 0.3	– 0.4	– 0.2	– 0.3
Gelnica	– 1.0	– 0.2	– 1.0	– 0.6	Sabinov	– 0.3	– 0.6	– 0.4	– 0.8
Hlohovec	– 0.3	– 0.4	– 0.3	– 0.4	Senec	2.2	4.1	1.9	3.5
Humenné	– 0.6	0.8	– 0.5	0.6	Senica	0.4	– 0.2	0.4	– 0.2
Ilava	0.5	– 0.9	0.6	– 0.8	Skalica	2.1	– 1.3	2.1	– 1.3
Kežmarok	– 0.4	0.4	– 0.4	0.1	Snina	– 0.5	– 0.6	– 0.6	– 0.6
Komárno	1.2	– 1.2	1.2	– 1.2	Sobrance	– 1.5	1.4	– 1.4	1.2
Košice-okolie	0.5	1.0	0.3	0.4	Spišská Nová Ves	– 0.3	0.4	– 0.3	0.3
Košice I–IV	1.1	0.5	1.2	0.6	Stará Ľubovňa	– 0.4	0.4	– 0.4	0.8
Krupina	– 0.4	– 1.0	– 0.4	– 1.0	Stropkov	– 0.9	– 0.4	– 0.9	– 0.4
Kysucké N. Mesto	– 0.7	0.1	– 0.7	0.0	Svidník	– 0.7	– 0.1	– 0.7	1.5
Levice	0.1	– 0.6	0.2	– 0.4	Šaľa	0.0	– 0.4	0.0	– 0.2
Levoča	– 0.5	0.0	– 0.5	– 0.2	Topoľčany	0.0	– 0.6	0.1	– 0.5
Liptovský Mikuláš	– 0.1	– 0.3	0.0	– 0.2	Trebišov	– 0.3	– 0.2	– 0.4	– 0.2
Lučenec	– 0.4	– 0.2	– 0.5	– 0.6	Trenčín	0.3	0.1	0.3	0.3
Malacky	– 0.6	2.3	– 0.6	3.3	Trnava	0.9	0.2	0.9	0.2
Martin	0.9	0.0	0.9	0.2	Turčianske Teplice	– 1.0	– 0.6	– 1.0	– 0.5
Medzilaborce	0.0	– 2.6	– 0.1	– 2.7	Tvrdošín	– 1.1	3.3	– 0.9	3.2
Michalovce	0.2	0.1	0.2	0.1	Veľký Krtíš	– 0.8	– 0.4	– 0.8	– 0.6
Myjava	– 0.8	– 0.3	– 0.8	0.0	Vranov n/T	– 0.6	0.2	– 0.6	0.1
Námestovo	– 0.4	1.6	– 0.3	1.2	Zlaté Moravce	– 0.9	– 0.3	– 0.9	– 0.2
Nitra	– 0.3	0.9	– 0.3	1.3	Zvolen	– 0.2	0.1	– 0.2	– 0.2
Nové Mesto n/V	– 0.5	– 0.2	– 0.5	0.1	Žarnovica	– 0.5	– 1.2	– 0.5	– 1.1
Nové Zámky	– 0.2	– 0.1	– 0.2	0.0	Žiarn/H	– 0.5	– 0.3	– 0.5	– 0.8
Partizánske	0.2	– 0.9	0.2	– 0.8	Žilina	0.1	0.7	0.1	0.5

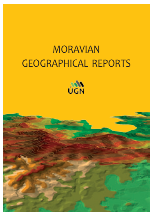
Appendix 3: Factor scores for districts of Slovakia in variants 65+ and 75+
Sources: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' calculations

Districts of Slovakia (LAU1)	Seniors per bed						Beds per 1,000 seniors			
	65+			75+			65+		75+	
	ModelA	ModelB	ModelC	ModelA	ModelB	ModelC	ModelB	ModelC	ModelB	ModelC
Bánovce n/B	244	168	121	130	63	60	6	8	16	17
Banská Bystrica	75	47	31	44	17	15	21	32	58	65
Banská Štiavnica	51	38	28	26	14	14	27	36	71	74
Bardejov	38	24	19	20	9	9	41	52	105	113
Bratislava I–V	67	43	28	35	16	14	23	36	61	71
Brezno	111	82	52	47	34	32	12	19	30	31
Bytča	78	49	38	37	18	17	20	26	55	58
Čadca	65	40	32	33	15	14	25	32	67	71
Detva	43	32	20	21	13	11	31	49	79	94
Dolný Kubín	72	44	33	40	17	15	23	30	58	66
Dunajská Streda	75	41	26	36	15	13	24	38	67	80
Galanta	38	24	17	19	9	8	42	60	114	130
Gelnica	124	88	59	52	36	33	11	17	28	30
Hlohovec	65	45	32	34	17	15	22	31	58	65
Humenné	165	111	61	72	40	35	9	16	25	28
Ilava	44	30	21	24	12	10	34	48	86	95
Kežmarok	103	58	47	48	21	21	17	21	47	47
Komárno	26	19	14	13	7	7	53	72	137	151
Košice-okolie	104	54	33	40	21	20	18	30	48	51
Košice I–IV	120	78	49	62	29	24	13	20	35	42
Krupina	27	20	13	12	8	7	50	77	125	144
Kysucké N.Mesto	120	77	58	58	29	27	13	17	34	37
Levice	49	36	26	26	14	12	28	38	73	81
Levoča	74	45	34	35	18	17	22	29	57	60
Lipt. Mikuláš	62	42	32	36	17	15	24	31	60	66
Lučenec	97	65	38	38	26	25	15	26	39	40
Malacky	214	119	124	157	42	38	8	8	24	26
Martin	59	40	24	33	16	12	25	41	63	86
Medzilaborce	11	10	8	6	4	4	102	130	228	253
Michalovce	70	44	32	36	16	15	23	31	63	65
Myjava	87	66	48	50	26	22	15	21	39	45
Námestovo	134	68	53	63	25	22	15	19	40	45
Nitra	162	105	88	100	40	36	9	11	25	28
Nové Mesto n/V	82	57	49	53	23	20	18	20	44	49
Nové Zámky	95	67	50	50	26	24	15	20	39	41
Partizánske	51	36	24	27	14	12	28	41	70	82
Pezinok	174	92	51	76	33	28	11	20	30	36
Piešťany	98	68	42	47	27	24	15	24	37	42
Poltár	46	35	24	21	14	13	29	42	72	74
Poprad	67	44	28	34	16	14	23	36	63	70
Pov. Bystrica	44	27	19	24	11	9	37	52	93	106
Prešov	96	56	39	48	23	21	18	25	44	48
Prievidza	55	37	24	28	14	13	27	41	70	78
Púchov	90	60	44	46	23	21	17	23	44	49

Appendix 2: continuation on the next page

Districts of Slovakia (LAU1)	Seniors per bed						Beds per 1,000 seniors			
	65+			75+			65+		75+	
	ModelA	ModelB	ModelC	ModelA	ModelB	ModelC	ModelB	ModelC	ModelB	ModelC
Revúca	107	74	42	43	26	24	14	24	38	41
Rimavská Sobota	79	55	34	32	21	21	18	29	47	48
Rožňava	53	37	27	28	14	13	27	37	71	76
Ružomberok	79	57	33	37	21	18	18	30	48	55
Sabinov	62	38	33	30	15	15	26	31	65	67
Senec	139	48	27	65	17	15	21	36	58	67
Senica	45	29	19	22	10	9	35	52	99	108
Skalica	21	13	9	11	5	4	77	112	212	243
Snina	63	42	33	32	17	16	24	30	59	62
Sobrance	410	303	251	210	128	122	3	4	8	8
Spišská N. Ves	120	74	56	62	28	27	13	18	35	37
Stará Ľubovňa	83	48	53	62	19	18	21	19	54	55
Stropkov	80	51	44	41	19	21	19	23	53	48
Svidník	48	30	81	85	12	11	33	12	84	88
Šaľa	46	32	24	26	12	10	32	42	84	101
Topoľčany	53	38	29	31	14	13	26	34	70	77
Trebišov	77	52	40	40	20	20	19	25	49	51
Trenčín	92	61	41	51	24	21	16	25	41	48
Trnava	69	43	30	36	16	14	23	33	63	69
Turč. Teplice	80	60	46	42	25	22	17	22	41	45
Tvrdošín	378	232	152	191	81	71	4	7	12	14
Veľký Krtíš	87	63	37	35	25	23	16	27	40	43
Vranov n/T	113	73	54	55	28	26	14	18	36	38
Zlaté Moravce	104	77	54	56	31	28	13	19	33	36
Zvolen	97	63	36	41	24	22	16	27	41	45
Žarnovica	41	32	22	20	12	12	31	46	80	87
Žiar n/H	105	74	33	35	29	27	14	30	34	37
Žilina	131	81	55	64	30	29	12	18	33	35
SLOVAKIA	**71**	**46**	**32**	**37**	**18**	**16**	**22**	**31**	**57**	**64**

Appendix 2: Availability of residential social services for seniors by model A, B and C for LAU1 Slovak regions, 2040
Sources: MLSAF SR (2018); SO SR, (2018); Šprocha et al., (2019); authors' calculations



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics
journal homepage: http://www.geonika.cz/mgr.html
doi: https://doi.org/10.2478/mgr-2022-0006

Late motherhood and spatial aspects of late fertility in Slovakia

Branislav ŠPROCHA [a] *, Anna FITALOVÁ [b]

Abstract

Shifting childbearing to later reproductive ages is reflected in all European populations. Late motherhood also changes, from the point of view of parity structure, since nowadays, the beginning of reproductive pathways is increasingly realised at the age of 35 and over more often. The regional dimension of this phenomenon is significantly overlooked, however. The main aim of this paper is to explore how the level and the impact of late motherhood has changed from a spatial perspective. We use Slovakia as a case study population characterised until the end of the 1980s by an early beginning of reproduction and its concentration in the first half of the reproductive period, and by relatively significant socio-economic, cultural and demographic differences. At the same time, we point out the changes in late motherhood in terms of parity structure. Finally, through linear regression models, we try to identify which of the selected factors may condition the differences in share of late fertility and the significance of first births at advanced reproductive ages.

Key words: *late fertility, parity structure, late motherhood factors, districts, Slovakia*

Article history: *Received 20 October 2021, Accepted 24 April 2022, Published 30 June 2022*

1. Introduction

Significant and dynamic transformational changes in reproductive behaviour have been displayed in Slovakia in the last three decades. One of the main impacts of the new social, political, economic and cultural conditions is the rapid abandonment of the early concentrated model of fertility, almost universal and within a narrow age-range. As several recent works (Beaujouan, 2020; Beaujouan and Sobotka, 2019; Sobotka and Beaujuoan, 2018) show, late motherhood and parenthood represent one of the important aspects of massive family transformation and reproduction in all developed countries. In this context, Prioux (2005) and Kohler et al. (2002) add that never in history have women in Europe been, on average, becoming mothers so late. At the same time, however, attention needs to be paid to the changing structural patterns of late motherhood in all developed countries.

Whereas in the past, it was mainly the period to complete the size of the family and thus children of higher birth order were born in the advanced reproductive age, the current changes caused the reproductive path of women only to begin in this age range (Prioux, 2005; Beaujouan and Sobotka, 2017, 2019). Broad attention is given to the late motherhood and overall reproductive ageing in the European area on the national level (e.g. Beaujouan and Sobotka, 2017, 2019; Billari et al., 2007; Prioux, 2005), but regionally these changes are analysed only exceptionally. Slovakia is no outlier in this respect; some partial studies (Potančoková et al., 2008; Šprocha and Bačík, 2020) even indicate an increase in the intensity of fertility in women of advanced reproductive age and its impact on overall fertility. Studies focusing directly on the issue of late motherhood and its development in the transformation period at the subnational level are absent. In this context, one should be aware that Slovakia represents an example of a small country in terms of population and size, but with significant regional socio-economic, cultural and demographic differences (Bleha et al., 2014).

The main aim of this paper, therefore, is to determine whether significant differences exist in terms of late motherhood. Another goal is to show if their spatial representation may have changed from the beginning of the

[a] Centre of Social and Psychological Sciences, Slovak Academy of Sciences, Bratislava, Slovakia (*corresponding author: B. Šprocha, e-mail: *branislav.sprocha@gmail.com*)

[b] Department of Economic and Social Geography, Demography and Territorial Development Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia

transformation period to the present, and which of several possible factors determine any differences. In this context, we try to identify the relationships and possible impact between selected socio-economic, cultural and demographic characteristics of regions and their populations, with the share of late fertility and its composition according to birth order (parity).

At the same time, however, it must be said that the definition of late motherhood is not so clear. For example, Moguérou et al. (2011) state that the age at which we can speak of a "late" mother or father is closely linked to a given period and country. Beaujouan (2020, p. 220) adds that the definition of late childbearing is subjective and embedded in the fertility levels and norms prevailing across time and space. Some older studies (e.g. Billari et al., 2007; Prioux, 2005) link late motherhood and an advanced reproductive age to 35 years and older. Recent studies (Beaujouan, 2020; Beaujouan and Sobotka, 2019; Sobotka and Beaujouan, 2018) work with a boundary at 40 years. Due to the later beginning of transformational changes in Slovakia, as well as the still very low current level of fertility in the last decade of the reproductive age (within the European area, see Šprocha and Bačík, 2020), the present study will work with the first-mentioned boundary of 35 years.

In addition, it is worth bearing in mind that this is not only a normative (Potančoková, 2009; Vidovičová and Gregorová, 2007) but also a biological boundary (Sobotka, 2010), beyond which the realisation of reproductive intentions is increasingly associated with several problems and with the growing risk of unsuccessful conception.

2. Theoretical background: Late fertility and its factors

The issue of late fertility has received much attention recently, but to date there is no specialised theory solely focusing on this phenomenon. In general, late fertility is based on theoretical frameworks anchoring the overall transformation of reproduction behaviours that has taken place in post-socialist countries since the early 1990s.

The first framework prioritises macro-structural change: the discontinuity in living conditions; the negative impact of factors associated with the transition from a centrally-managed to a market economy; and social anomie formation in post-socialist societies (Becker, 1981; Frejka, 2008). Especially in the initial phases of economic transformation, the uncertainty and discontinuity of living conditions may have brought about difficulties with the implementation of reproductive plans. With continuing economic transformation and the development of market mechanisms, some other structural factors (e.g. a tightening job market, a growing degree of labour market competition, new career opportunities, and rising direct and indirect costs of children) (Frejka, 2008) began to come to the fore, which may have contributed to the continuing increase in the intensity and share of late fertility.

A second theoretical framework is based on value and normative changes brought into society by the transformation period in post-socialist countries. The most comprehensive description of such changes is found in the theory of the second demographic transition (Lesthaeghe, 1995; van de Kaa, 1987). These changes are characterised primarily by the long-term transformation of values and life orientations towards individualism and self-expression, which have been supported by the emergence of new opportunities. The main feature is a strong interest in self-realisation, freedom of choice, personal development and lifestyle, and emancipation – factors which are reflected in the concepts of family formation, attitudes towards fertility regulation, and motivations for parenthood (van de Kaa, 1997).

Especially relevant for countries of the former Eastern Bloc (Won Han and Brinton, 2022), are the issues of gender equality in paid and especially unpaid work, the possibilities of reconciling work and caring for the family and household, and the associated direct and indirect costs of lost opportunities, all strongly connected (McDonald, 2000).

Another important framework explaining the increase in intensity and late fertility is the postponement transition theory (Kohlet et al., 2002). As shown by Beaujouan (2020), late parenthood in recent decades has been linked mainly to the later onset of reproduction pathways. Several authors (e.g. Mills and Blossfeld, 2005; Adsera, 2004) indicate that the combination of an unstable position in the labour market, the threat of unemployment, insufficient salary evaluation and the need to work part-time, can all together create a milieu in young people where it is rational for them to strategically postpone fertility to a more appropriate period.

As Billari et al. (2007) and Beaujouan (2020) add, it is now socially acceptable and often economically necessary to start a family much later. This is subsequently reflected in a sharp rise in late first and second births, and in overall late fertility over recent decades (Beaujouan, 2020). Although the process of voluntary and planned postponement of the beginning of reproductive pathways may be an important factor in the increasing impact of late fertility, it may not be a decisive factor. Several analyses (Berrington, 2004; Šťastná et al., 2017, 2019; Slabá et al., 2021; Toulemon and Testa, 2005) confirm that postponed reproductive plans are often not implemented by women in terms of the number of children and the age at which they want to give birth (Slabá et al., 2021). In this sense, Šťastná et al. (2017, 2019) point to the aspect of unplanned postponement, which can be one of the important factors in the growing impact of late fertility.

Research into the factors leading to late fertility is also important in this regard; however, the analysis of regional factors that may be directly related to late motherhood has so far only received limited attention. Spatial differences in late fertility can be the result of the characteristics of certain regions as well as due to differences in some important structures of their populations (Duchęne et al., 2004). In general, some authors (de Beer and Deerenberg, 2007; Duchęne et al., 2004; Hank, 2001) have identified two main groups of regional characteristics that can be related to fertility. The first group comprises economic opportunities and constraints that create local living conditions. In line with Beaujoan (2020), the rise in unemployment and worsening economic security are important variables for late fertility. According to some studies (Gauthier and Hatzius, 1997; Kravdal, 2002), high unemployment and low wages create an unfavourable reproduction climate. In such an environment, it is difficult for individuals to make long-term decisions and it is thus possible to expect their postponement as a reaction to structural barriers of parenthood (Hašková, 2006). On the other hand, Friedman et al. (1994) show that for some groups of women with low cultural capital and having difficulty entering the formal labour market, an earlier start to reproductive careers may be one way to reduce their insecurity. Hank (2001) also ranks the occupational structure in the local labour market among important regional economic fertility factors.

Following de Beer and Deerenberg (2007), the second group of regional characteristics consists of cultural factors which can affect regional differences in late fertility through different attitudes towards families and children. Cultural differences at the regional level are often measured indirectly using selected determinants assumed to reflect the differences in norms, values, and attitudes towards fertility (de Beer and Deerenberg, 2007). Education is one of the most frequently applied indirect cultural factors. According to work by Toulemon (2005), late motherhood has become more common among more educated women. In the case of higher education, it is to be expected that not only the direct impact of longer studies will be present (e.g. Blossfeld and Huinink, 1991; Kravdal, 1994; Kravdal and Rindfuss, 2008) but that indirect effects would be the most prominent. It was among highly educated women that Berrington (2004) found a trend leading to the long-term postponement of family formation.

Religiosity is also one of the very common cultural factors. While some older research (Andorka, 1978) present it as one of the strongest and most consistent factors, some recent studies (Frejka and Westoff, 2008; Sobotka and Adigüzel, 2002; Zhang, 2008) point to a weakening of the religiosity effect and a reduction in differences between religions. De Beer and Deerenberg (2007) also included the degree of urbanisation among the important cultural factors of spatial differences in fertility. Norms and attitudes towards children and families can have a stronger impact in the rural environment, as social control and direct social impact play more important roles in those areas.

According to Kulu (2013) and Kulu and Vikat (2007), the lives of young people in urban areas (especially in the largest municipalities) are more expensive and time-consuming. Direct and indirect costs for the care of children are higher. Kulu (2013) adds that it is possible to identify the specific selective migration of people planning to start a family into the hinterland of large cities and smaller municipalities, generally, as they are more suitable for the care and upbringing of children. On the other hand, larger towns are more likely to be in demand by people who (thus far) do not have reproductive aspirations and who are trying to forge a career or find work.

As mentioned above, in addition to regional characteristics in spatial differences in late fertility, demographic variables may also have an effect. As stated by de Beer and Deerenberg (2007), the structure of the regional population affects fertility because fertility differs between subcategories of the population. In general, the influences of marital status and the presence of ethnic groups are the most frequently discussed in this regard.

The partnership situation and the marital status of women are also important factors for late fertility (Toulemon, 2005; Beaujoan, 2020). Several studies (Berrington, 2004; Szalma and Takács, 2012; Miettinen et al., 2015) have identified clear relationships between a lack of suitable partners, the postponement of marriage, celibacy, late fertility, and even childlessness. This interconnection is recognised in the European area even today (Miettinen et al., 2015). Toulemon (2005) has pointed out the growing prevalence of late motherhood among single women and among women living in other partnerships. Beaujouan (2020) has highlighted the importance of re-marriage (or re-partnering) in the growth of late fertility.

When analysing regional differences in the intensity and share of late fertility in Slovakia, it is not possible to ignore ethnic composition. In segregated Roma settlements, the birth of higher-order children is more frequent (Šprocha and Bleha, 2018), which could affect the regional level and the share of late fertility.

From the factors of late fertility operating at the aggregate level, it is necessary to identify those that are individual in nature. Some research (Beaujouan, 2022) shows that a significant number of childless women still wish to become mothers at an advanced reproductive age and that their representation is growing. This indicates a certain individual change in attitudes towards late motherhood, and it implies a considerable strength of obstacles acting against motherhood at a younger age (more appropriate for the realisation of reproductive intentions) (Beaujouan, 2022). It is problematic at the individual level, however, to associate late fertility with the dominant planned postponement of parenthood until this age. In this sense, it is necessary to realise that reproduction is the result of sequential decision-making, where people repeatedly make decisions and re-evaluate them under the influence of new experiences and circumstances (Hašková et al., 2019).

It is also important to distinguish between groups of women who became mothers for the first time at an advanced reproductive age and to whom a second or third child was born. Their reproductive history can be very different, and the factors that influenced the birth of a given child can be specific. In the case of childless women who have become mothers aged 35 and over, this may be due to a long (and often re-evaluated) postponement in the context of the non-fulfilment of personal or a partner's common preconditions for motherhood (e.g. housing, work, and partner situation). Second and possibly higher-order children born at an advanced reproductive age may more often be the result of a planned family size with a certain shift (e.g. due to the later birth of the first child), or they may be the result of an unplanned conception. As confirmed by several studies (Slabá et al., 2021; Šťastná et al., 2017, 2019), the birth of the first and second child at an advanced reproductive age can also often be the result of an unplanned postponement. It turns out that the most important individual factors of late fertility can include the health status of the woman and partner (and especially age-related problems to getting pregnant), labour market problems, and overall material conditions, as well as the absence of a suitable partner (Šťastná et al., 2017, 2019). It can therefore be said that several of these individual factors are similar in nature to those identified at the aggregate level.

In terms of the above theoretical background and existing empirical knowledge, there can be an expectation for the persistence of significant spatial differences in the intensity of late fertility in Slovakia. The impact of late fertility on overall fertility also appears to have increased since the first half of the 1990s in virtually all districts. As significant transformational changes in terms of the parity structure of late fertility are confirmed at the national level (Šprocha and Fitalová, 2022), these are also expected at the regional level. Due to the effects of various regional specifics, however, it can be assumed that there has been some spatial diversification in the influence of individual parity groups.

3. Data and methods

The main data source is the anonymised primary database of the Statistical Office of the Slovak Republic (SO SR) from the annual comprehensive survey of the Population Council 2–12 Birth Report for the period 1992–2019.

It contains all collected data on children born and their mothers with permanent residence in Slovakia. Given the information on permanent residence, mother's age at birth and vitality, it was possible to classify all relevant demographic events (or their records) into individual regions of Slovakia. The objectives of the research as well as the population size of some districts indicated that we work with 5-year time intervals. The analysis looked more closely at the first period 1992–1996, which characterised the beginning of transformation processes. The second period of 2015–2019 represents the latest known situation. This enables us to identify not only development-related changes in the level and significance of fertility in the advanced reproductive period, but also possible shifts in regional differences. An important input for the calculation of selected fertility indicators was the database of the social structure of women by age and district of permanent residence. It is available from the primary balanced SO SR database for the years 1992–1995 and the SO SR DATACube online database for the years 1996–2019.

Indicators of fertility quanta in the form of age-specific fertility rates for all 79 districts of Slovakia were constructed for the observed 5-year periods (t):

$$f_x^{t,d} = \frac{N_x^{t,d}}{P_x^{t,d}}$$

where

- $f_x^{t,d}$ is the age-specific fertility rate of women of age (x) in period (t) in district (d);
- $N_x^{t,d}$ is the number of live births to women of age (x), in period (t) in district (d); and
- $P_x^{t,d}$ is the number of women aged (x), in period (t) in district (d).

From this we derived the cumulative fertility of women aged 35 and over:

$$f_{35+}^{t,d} = \sum_{x=35}^{49} \frac{N_x^{t,d}}{P_x^{t,d}}$$

as well as contributions to the total fertility rate:

$$pf_{35+}^{t,d} = \frac{f_{35+}^{t,d}}{TFR^{t,d}} \cdot 100 = \frac{\sum_{x=35}^{49} \frac{N_x^{t,d}}{P_x^{t,d}}}{\sum_{x=15}^{49} \frac{N_x^{t,d}}{P_x^{t,d}}} \cdot 100$$

where $TFR^{t,d}$ represents the total fertility rate in period (t) in district (d).

In the next analysis, we expanded the previous indicators to include the aspect of biological parity by constructing age-specific fertility rates of the first, second, third and further order. These rates were derived by analogy to achieve total fertility of women aged 35 and contributions of individual parity groups to total fertility in the advanced reproductive period. These enabled us to determine what changes in late motherhood have been realised in the Slovak districts in terms of the parity structure. In addition, based on the quartile position of the districts in terms of the contributions of individual parity groups to total fertility in the advanced reproductive ages, a typology was developed for the period 2015–2019.

Multiple linear regression models were used to identify the factors that could account for the variations in the identified (current) regional differences. Two models were developed. The first model determines the fertility rates of women aged 35 and over from the total fertility in districts in 2015–2019. In the second model, the dependent variable was the share of the first birth rates from total fertility in advanced reproductive age. As independent (explanatory) variables, we use some indicators available at the district level from 2015–2019 (or from 2011: see Note 1). The source of data is the database of the Statistical Office of the Slovak Republic DATACube and data from the Ministry of Labour, Social Affairs and Family. If possible, we work directly with data for the population of women in childbearing age. In line with the previous theoretical background and the availability of data at a district level, we worked with three main groups of independent variables:

- Socio-economic indicators reflecting regional differences in opportunities and constraints: unemployment rate; the percentage of long-term unemployed; employment rate (women); average monthly nominal wage (women); average number of job seekers per 1 job offer; the percentage of recipients of benefits in material need over the age of 15; the percentage of employed women in the tertiary sector; and the percentage of women in management positions or as legislators;
- Cultural factors[1] indirectly reflect regional differences in norms, values and attitudes towards fertility: mean years of schooling (women); the percentage of women with basic education and without education; the percentage of women without religious affiliation; and the proportion of women who live in municipalities with 5,000 or more inhabitants; and
- Demographic factors that reflect differences in the selected population structures in districts: the percentage of at least once married women of childbearing age; the percentage of population living in Roma segregated settlements; and the percentage of persons other than Slovak nationality.

Models were estimated by stepwise multiple regression in IBM SPSS software. The basis of this method is in selection of an independent variable, the addition of which into the regression model will contribute the most to the explanation of the variability of the dependent variable. A standardised regression coefficient is then calculated for the independent variable that entered the regression model. In the second step, one of the remaining independent variables, which contributes most to explaining the variability of the dependent variable, is added into the existing regression model, and standardised regression coefficients are calculated for both independent variables. The procedure is repeated in phases until the model includes all independent variables contributing significantly to the explanation of the dependent variable. This approach gives us an idea of which independent variables have the most influence on the variance of the dependent variable and which, on the contrary, have the smallest contribution. The aim is to find the potentially best model accounting for current regional differences in late motherhood in Slovakia.

[1] The source of data is the Population and Housing Census 2011 and the Atlas of Roma communities in Slovakia (2019)

4. Results

4.1 Fertility intensity in advanced reproductive age

The total fertility rate of women aged 35 and over was relatively low in almost all districts of Slovakia in the first half of the 1990s. This confirms for Slovakia the model of a significant concentration of reproduction in the first half of the reproductive years, and only minimal effects of advanced reproductive age. Up to 53 of all 79 districts showed fewer than 0.1 children per woman of advanced reproductive age (see Fig. 1).

In another 22 districts, the fertility level of women aged 35 and over ranged from 0.1 to 0.2 children per woman. Only in four districts in the north (Námestovo) and northeast of Slovakia (Kežmarok, Stará Ľubovňa, Sabinov) did it exceed the limit of 0.2 children. Overall, the higher late fertility in some units in the north and northeast of Slovakia was mainly due to a significantly higher share of third and higher-order fertility (Fig. 1). In the mentioned four districts, it reached a significantly above-average level (90% and more).

The results of our analysis confirmed that in all districts the fertility of women aged 35 and over has increased. It also turned out that this process was spatially highly differentiated. The rate of late motherhood increased fastest in the capital city's districts and its wider hinterland. In these areas, several analyses (Jurčová et al., 2010; Bleha et al., 2014) haver also confirmed the dynamic delay in the onset of the reproductive pathways.

This link between longer postponement and the dynamics of increasing late fertility is also supported by the finding that most of these districts are also characterised by the highest fertility parity one in advanced age (see Fig. 2). The districts of Bratislava have a specific position, where the late fertility of the first order exceeds the level of 0.1 first child per woman. It is not possible, however, to talk only about the process of postponing maternal starts to an advanced reproductive period as the primary factor of increasing late fertility in these districts. A more detailed analysis of fertility by parity also identified, in this area, the above-average level of birth of second children.

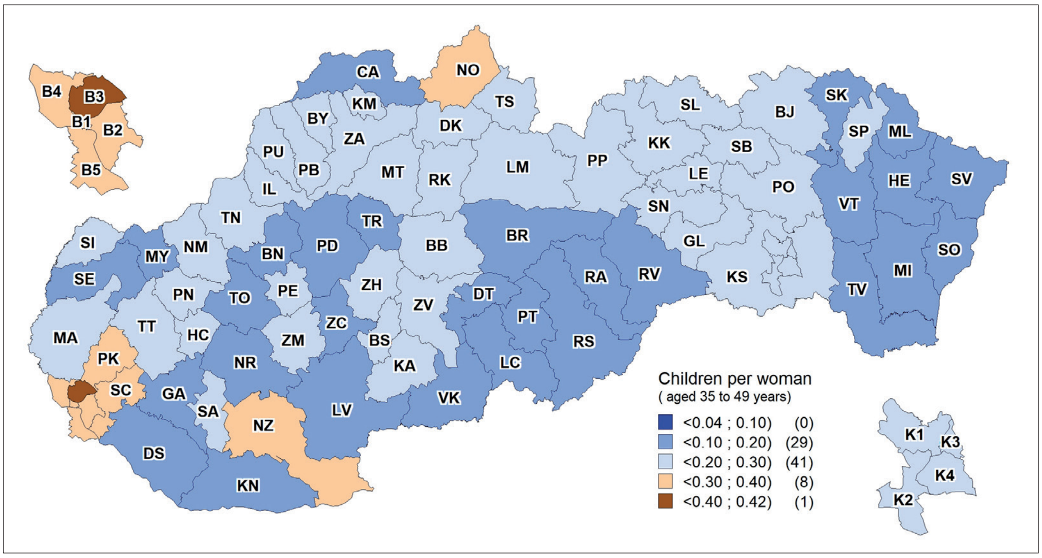


Fig. 1: Late fertility in districts of Slovakia, 2015–2019
Sources: SO SR 2015–2019; authors' calculations

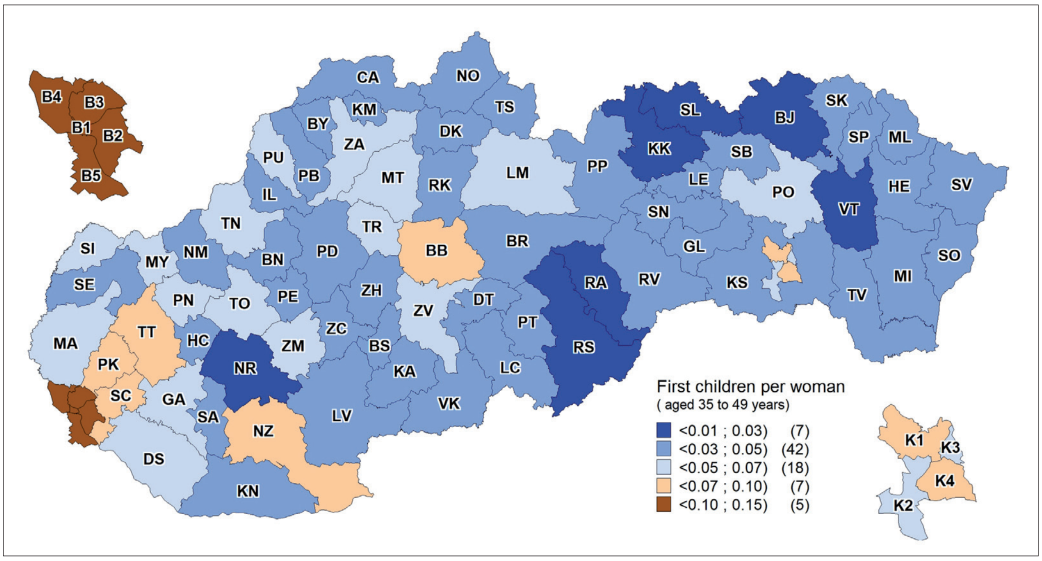


Fig. 2: Late first order fertility in districts of Slovakia, 2015–2019
Sources: SO SR 2015–2019; authors' calculations

The situation in some districts of eastern Slovakia, which can also be included in the group of regions with faster growth of late motherhood, is specific. In their case, however, it turns out that the fertility of the first order in advanced reproductive age is one of the lowest (Fig. 2). On the contrary, these districts represent an area with significantly above-average fertility of the second and especially the third and higher order (see Fig. 4).

4.2 The importance of late motherhood for total fertility and its changes

The significance of advanced reproductive age fertility was generally low in all districts in the early 1990s (Fig. 3). The share of late fertility in total fertility was over 10% only in Námestovo district, while 32 regions did not even reach 5%. Another 24 districts ranged from 5 to 6% (Fig. 3). The observed increase in the late fertility rate in all regions of Slovakia, however, contributed to a greater impact on total fertility. In the last period 2015–2019, the contributions of late fertility did not exceeded the 10% boundary in only two districts. On the other hand, a total of 40 districts were already above 15% and in 6 districts fertility in advanced reproductive period accounts more than a fifth of total fertility. That includes all five districts of Bratislava and Košice I district. We can, however, also identify some other districts with a significant impact of late fertility on the overall reproduction rate. We can include in this group mainly districts from the broader area of the capital, as well as districts of central Slovakia with important economic centres. These administrative regions also generally belonged to the group with the fastest-growing percentage of late motherhood on total fertility in Slovakia.

A significantly different situation is developing in most of the districts of eastern and southern central Slovakia. This area is characterised by the lowest percentage of fertility among women aged 35 and over on total fertility. Several districts in this area experienced only a gradual change in the age profile of fertility. The model of a relatively early beginning of reproductive pathways and only a limited reproduction postponement to the second half of the reproductive years remains significant.

4.3 Transformation of the parity structure of late motherhood

A specific feature of the population reproductive model of former Eastern Bloc countries was the considerable concentration of reproduction in a narrow age interval in the first half of the reproductive years with an early motherhood and a gradual intercohort tendency towards the two-children family model. As a result, childbearing in the second half of the reproductive age had an ever smaller effect on the overall fertility intensity, mostly with children of higher birth order.

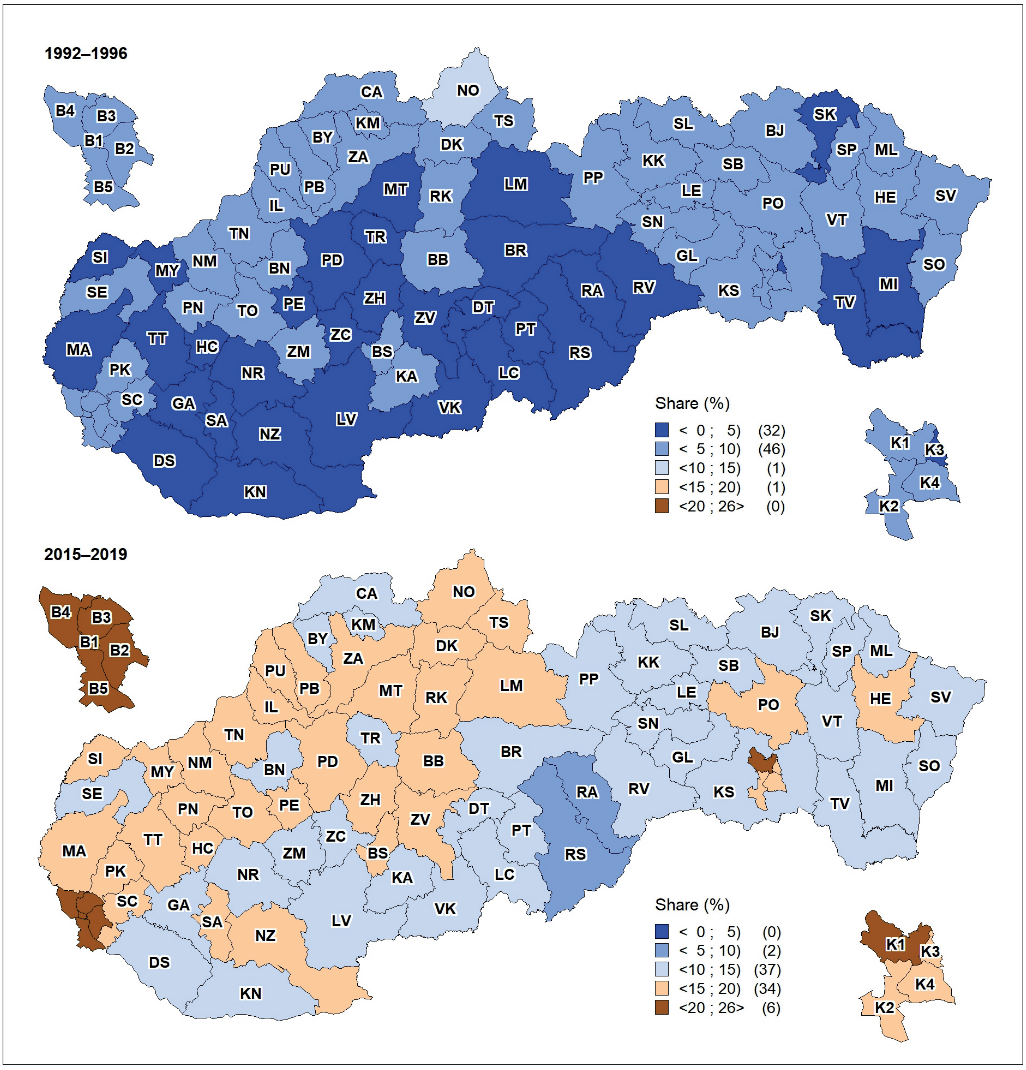


Fig. 3: Share of late fertility in total fertility in districts of Slovakia, 1992–1996 and 2015–2019
Sources: SO SR 1992–1996, 2015–2019; authors' calculations

In the first half of the 1990s, the higher level of late motherhood in some northern and eastern Slovak districts was mainly due to the more frequent births of third and further children. Overall, the birth significance of this parity group exceeded up to three quarters in a third of the districts (Fig. 4). Also, however, we find the influence dominance of the birth of third and further children in other regions. According to our data, in principle, their share was only below 50% in four capital districts. In the other 11 districts, it ranged from 50 and 60% (see Fig. 4).

Developments in the following decades brought significant changes, mainly based on increasing the intensity of the birth of the first and the second child. The most significant increase in maternity onset at an advanced reproductive age was seen in the urban districts of the capital, Košice and some regions in the suburban area of Bratislava and central Slovakia with important economic centres. In contrast, in the east and north-east of the country, clearly, the lowest shift of the birth of the first children to women aged 35 and over is seen. This area was mainly affected by the increasing intensity of second pregnancies and, in some cases, the birth of third and higher order children.

In the first half of the 1990s, the share of first-order fertility in total fertility at an advanced reproductive age exceeded 20% in only five districts of Slovakia (Fig. 4). In most districts, especially in western and central Slovakia, its share ranged from 10 to 20%. In eastern and northern Slovakia, the share of first-order fertility was even lower. An extremely low level was identified in five districts in the northern part of central Slovakia (Čadca and Námestovo) and eastern Slovakia (Kežmarok, Stará Ľubovňa, and Sobrance), where first-order fertility did not account for even 5% of total fertility at this age (Fig. 4).

The situation in the period 2015–2019 witnessed a significant change. Above all, the share of first-order fertility in total late fertility was strengthened in virtually all districts. The influence of this parity group grew most dynamically in most districts of western and a large part of central Slovakia. The opposite situation was found especially in eastern Slovakia, with the exception of the easternmost districts and the city districts of Košice. As a result of these changes, this parity group had the greatest influence from 2015 to 2019 in the capital (more than a third of the total late fertility rate), while in several regions in the north and east of the country it reached only a below-average level (less than 20%). From the above, it is clear that despite a significant increase in first births, this parity group did not hold a dominant position in late motherhood formation in any of the districts.

In the first half of the 1990s, the proportion of second-order fertility at an advanced reproductive age ranged from 5 to 35%. Above-average values were mainly identified in some city districts of Bratislava, in the district of Myjava (with more than 30%), and in the city districts of Košice. Some districts in the south of western and central Slovakia and some other units with important economic centres can be included in this group (Martin, Banská Bystrica district). The situation was quite the opposite, especially in the north of central and eastern Slovakia, where the fertility of the second order did not make up even a tenth of total late fertility.

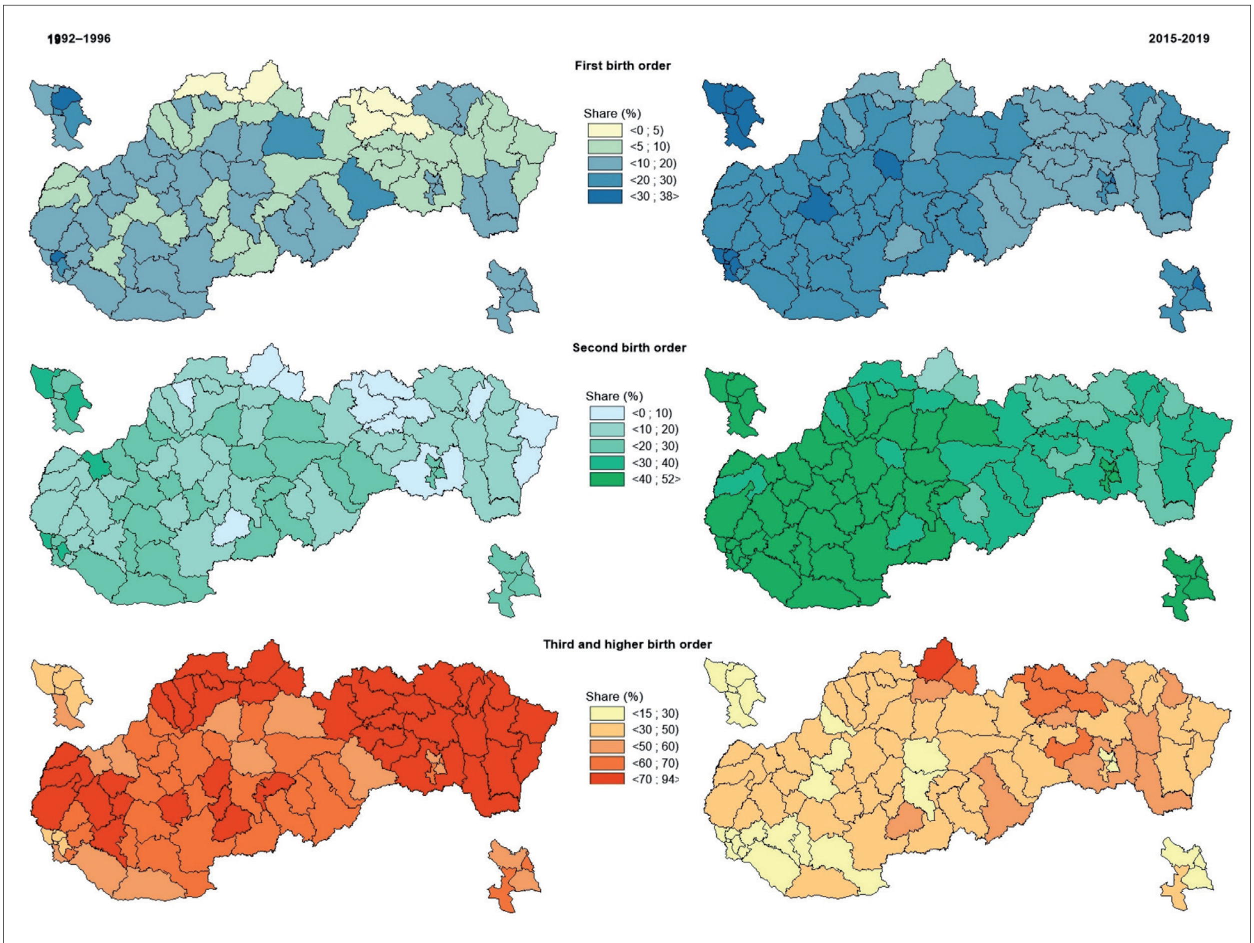


Fig. 4: Share of late fertility by birth order in total late fertility in districts of Slovakia, 1992–1996 and 2015–2019
Sources: SO SR 1992–1996, 2015–2019; authors' calculations

From 2015 to 2019, there was a significant increase in the impact of second-order fertility on overall late fertility in virtually all districts. The intensity of the birth of second children was already contributing to a decisive influence on the overall late fertility in more than 40 districts. These are mainly the districts of the west and south-west of Slovakia and the city districts of Košice, as well as some districts of central Slovakia with important economic centres. In these areas, it makes up 40 to 50% (Fig. 4). Northern districts and some districts in eastern Slovakia remained in a different situation.

In this area, the fertility rate of second children at an advanced reproductive age is still less than 30%. In the first half of the 1990s, with the exception of four Bratislava districts (Bratislava I, II, III, and IV), the share of fertility of the third and higher order accounted for more than half of the total late fertility in Slovakia. The dominance of this parity group on late fertility in this period in virtually all districts is documented by other findings. In 54 out of 79 districts, the fertility of the third and higher order accounted for more than two thirds, and in the fifteen administrative units with the highest share, even the fertility of the third and higher order accounted for more than 80% of fertility at an advanced reproductive age. As can be seen from Figure 4, this was mainly the case in districts of northern and eastern Slovakia. From 2015 to 2019, all districts of Slovakia saw a relatively significant decrease in the share of fertility of the third and higher order in total late fertility. The smallest dynamics of this process can be found in several districts of eastern and northern Slovakia. Due to this, these areas are still characterised by a significantly higher share of this parity group in late fertility. In the Námestovo district, this share exceeded 72%. In the other five districts of northern and eastern Slovakia (Stará Ľubovňa, Sabinov, Kežmarok, Gelnica, and Tvrdošín), it made up 60 to 66%. Another nine districts were above the level of 50%. Again, this was mainly in northern and eastern Slovakia (Fig. 4). The situation was quite the opposite in the city districts of Bratislava, Senec, Banská Bystrica, and in the district of Košice III, where the fertility of the third and higher order does not make up a quarter of the total late fertility (Fig. 4). Overall, the districts of western Slovakia have a lower impact on the fertility of third and other children on fertility in the advanced reproductive period.

Given the structure of late fertility by parity, it is possible to identify two main groups of districts in Slovakia from a spatial point of view, which can still be differentiated into two partial subgroups (see Fig. 5). Cluster 1a is characterised by the highest proportion of first-order fertility and a high weight of second-order fertility with the lowest impact of the intensity of birth of third and further children on late fertility. This can be seen mainly in the districts of Bratislava and Košice as the two largest cities, in southwestern Slovakia, and in two districts in central Slovakia with important economic centres (Banská Bystrica and Zvolen). The majority of districts in western Slovakia, together with some districts in central Slovakia with larger centres (Martin, Žilina, and Liptovský Mikuláš), and the district of Košice II form cluster 1b. This is characterised by a high proportion of first- and second-order fertility and a low proportion of third and subsequent children in fertility at an advanced reproductive age. The opposite setting of late fertility is in the clusters of districts in the north of central Slovakia and in most of eastern Slovakia (2a and 2b). In cluster 2a, there is the highest share of fertility of the third and higher order with the lowest representation of fertility of the first and second order. Cluster 2b consists of districts with a high proportion of fertility of third and subsequent children and a low proportion of the first and second order. The clusters 2a, 2b and 2c are formed by districts with mixed structures of late fertility according to parity. As can be seen from Table 1, cluster 2a is characterised by a relatively high proportion of second, third, and other children with low first-order fertility. Cluster 2b is a specific polarised space with a high proportion of first and third and higher fertility at low birth rates of second children. The last identified cluster (2c) had a high second-order fertility effect with low proportions of the first and third and subsequent children.

4.4 Some factors in spatial differences of late motherhood

Statistical findings (the F-Ratio in the Analysis of Variance) indicate that independent and statistically reliable factors significantly predicted both dependent variables. When explaining the share of late fertility in total fertility in the districts of Slovakia, the values of R, R Square, and Adjusted R Square were even at or above the limit of 90%. This highlights the suitability of the model and its considerable explanatory power in the context of the share of late fertility

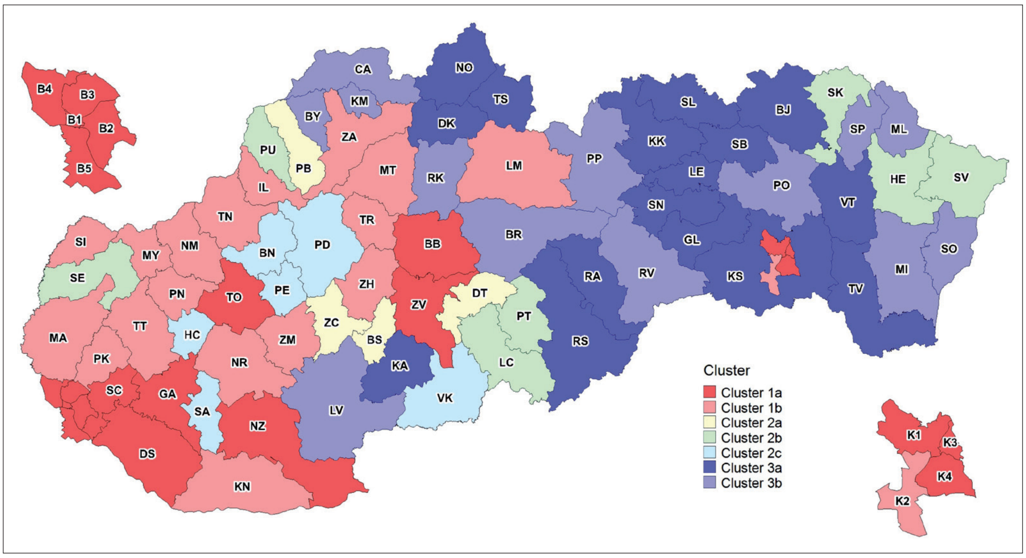


Fig. 5: Typology of districts in Slovakia according to the share of late fertility by birth order in the period 2015–2019
Sources: SO SR 2015–2019; authors' calculations

Cluster	Main characteristics of late fertility	Average share of late fertility by birth order in total late fertility (%)		
		First order	Second order	Third and higher order
1a	The highest first order; high second order; lowest third and higher order	31.1	44.3	24.6
1b	High first and second order; low third and higher order	24.6	43.1	32.3
2a	High second and third and higher order; low first order	20.6	41.7	37.7
2b	High first and third and higher order; low second order	23.5	35.2	41.3
2c	High second order; low first and third and higher order	21.1	45.5	33.4
3a	The lowest first and second order; the highest third and higher order	14.9	27.6	57.5
3b	Low first and second order; high third and higher order	19.9	35.7	44.4

Tab. 1: Characteristics of identified clusters of districts in Slovakia according to the structure of late fertility by birth order, 2015–2019. Sources: SO SR 2015–2019; authors' calculations

in total fertility. The second model, which tries to explain the influence of first-order fertility on late fertility, did not reach such high values of R, R Square, and Adjusted R Square. Nevertheless, a level above 70% (in the case of R Square and Adjusted R Square) means that the model is sufficient for present needs. Both models saw a significant reduction in the number of explanatory variables and the selection of only the most important ones.

As can be seen from Table 2, the largest part of the variability of the share of late fertility in districts in Slovakia is accounted for by the variable 'length of the education of women'. It is clear that the higher the value of this indicator, the greater the impact of late motherhood on overall fertility. Later on, the model was enriched with other variables based on the significance of their influence. Their influence on the model and its explanatory power were significant for the resulting model. It is interesting that in explaining differences in the impact of late fertility on overall fertility in the districts of Slovakia, the factors of socio-economic conditions prevail among the other indicators added to the model. Apart from this group, only the share of people in segregated Roma settlements was included in the model.

This result may thus indicate the significant impact of economic opportunities and constraints at a regional level in relation to late fertility. The direction of influence of the given indicators is also important. While the share of fertility at an advanced reproductive age is increasing alongside better average monthly nominal wages and employment in the tertiary sector, indicators showing economic problems in the region (unemployment rate and job seekers per job offer) reduce this share.

It is also important to note that the effect of a higher proportion of people from segregated Roma settlements runs against the trend of increasing the share of late fertility in total fertility. One explanation could be in the early beginning of reproductive pathways, which may also imply an earlier completion of the size of the family. In this regard, it is necessary to realise that the effort to regulate the number of children has been identified even in the segregated Roma settlements (Šprocha and Bleha, 2018). As a result, a relatively rapid decline in fertility was identified in this environment after the age of 25. The differences in late fertility compared to the Slovak average are therefore relatively small.

These findings are largely supported by the identified spatial differences in the share of late fertility. Districts primarily in western Slovakia and partly in central Slovakia with a higher share of late fertility have a more frequent occurrence of women with a higher level of education and are areas with better economic conditions, lower unemployment rates, and more frequent employment in the tertiary sector. By contrast, several eastern and northern districts in Slovakia are characterised by worse economic conditions and shorter lengths of education, which ultimately is probably largely reflected in their low to very low shares of late fertility. As many of these regions are also marked by an early start to reproduction, it can be expected that family size is completed here earlier than in the advanced reproductive period.

Indicators in model	Unstandardised Coefficients		Standardised Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	− 25.415	4.834		− 5.257	0.000
Mean years of schooling (women)	2.844	0.394	0.498	7.214	0.000
Unemployment rate (total population)	− 0.070	0.036	− 0.172	− 1.956	0.054
Employment in tertiary sector (women)	0.039	0.011	0.159	3.558	0.001
Population in Roma segregated settlements (total population)	− 0.089	0.029	− 0.228	− 3.044	0.003
Average monthly nominal wage (women)	0.004	0.001	0.146	2.785	0.007
Job seekers per 1 job offer (total population)	− 0.002	0.001	− 0.092	− 2.142	0.036

Tab. 2: Multiple linear regression between share of late fertility in total fertility in districts of Slovakia and selected indicators, 2015–2019 (Model summary: R = 0.949; R Square = 0.901; Adjusted R Square = 0.892)
Source: authors' calculations

The second model attempted to explain the influence of selected variables on the regional differences of the proportion of the first childbearing in women aged 35 and over in the overall level of late motherhood. The main explanatory factor in this model became the mean years of schooling (Tab. 3). The length of education in the districts of Slovakia increases the share of late fertility and emphasises the fertility of the first order. This is also supported by previous findings, where in districts with the highest mean years of schooling (especially in the west of Slovakia and in city districts in Bratislava), there was generally a higher proportion of first-order fertility and vice versa. The employment rate of women also had a positive effect on increasing the impact of first-order fertility on late fertility. This may be related to the problems of reconciling work and home and family care as well as the lack of institutional care for young children, which, with the growing employment of women, increases the impact of first children on late fertility in some regions. The cost of lost opportunities for employed women can be equally important. The unfavourable economic conditions of a given region may also prove to be an important factor. The growing share of first-order fertility in late fertility seems to be influenced by the problems associated with women's employment and by the degree of maternal deprivation and the need to receive social benefits.

The last two indicators that were included in the model included the percentage of people of non-Slovak ethnicity and the share of women living in municipalities with more than 5,000 inhabitants. In this sense, it was confirmed that urban spaces could be a factor in Slovakia that influences the timing of family formation and their more frequent shift to an advanced reproductive age. Explaining the ethnic indicator seems more complicated. In the case of persons of Roma ethnicity, it was not possible to expect their positive impact on the higher share of first-order fertility in total late fertility due to the very early timing of the beginning of reproductive pathways; however, later maternal starts were identified in some other ethnic groups in Slovakia. In this context, it is also necessary to discuss the mechanisms of postponing the reproductive intentions of people living in non-Slovak ethnic environments as a strategy enabling their easier establishment in society.

5. Discussion and conclusions

Our results confirmed the existence of relatively significant spatial differences in the late fertility level and share of late fertility in total fertility. It is mainly the area of the capital and its wider hinterlands, the districts of the second largest city in Slovakia and some regions of western and central Slovakia with important economic centres. Late fertility also plays an important role in some districts in north and north-east Slovakia. Identified changes in the parity structure of late motherhood at the subnational level were associated with the conclusions of Toulemon (2005). In general, the birth of the first and second children increasingly takes place at an advanced reproductive age. On the other hand, there were relatively considerable regional differences.

We have identified a total of three main types and their several subtypes of district clusters according to the structure of late fertility by birth order. Especially in districts in the west of Slovakia, in the city districts of Košice and some districts with important economic centres in central Slovakia, we can find a significant impact of first and second children and, conversely, a low to very low fertility rate of third and subsequent children. This is in line with some other studies from non-ECE countries (Berrington, 2004; Kulu, 2013; Toulemon, 2005), which found among more educated women and people living in cities and especially in the largest municipalities, a more significant shift to maternal onset. In this environment, higher direct and indirect costs (Becker, 1997) in connection with caring for a child/children at a younger age, the need for flexibility, mobility and competitiveness are to be expected (McDonald, 2000, 2002). This is probably also related in this area to the more frequent tendency of women to build careers (Hakim, 2003), that takes precedence over long-term commitments such as motherhood. Normative and value intentions related to higher education, social and cultural living space and the higher anonymity of the urban environment, can also be important postponement aspects (Potančoková, 2009). The influence of individual factors conditioning the unplanned postponement of childbearing to an advanced reproductive period also remains an issue. On the other hand, some districts of northern and eastern Slovakia are still characterised by a model of late fertility with a very low to low share of first and second order fertility rate and the highest impact of the birth of third and subsequent children. At the same time, however, it must be said that late fertility in this area is generally lower.

These districts combine a lower rate of urbanisation, poorer socio-economic conditions, specific ethnic structure and, especially in the north, a factor of higher religiosity (Bleha et al., 2014; Halás, 2008; Korec et al., 2005). In addition, we can identify a lower quality of educational attainment. It seems, therefore, that the earlier start of reproductive pathways and the less frequent use of advanced reproductive

Indicators in model	Unstandardised Coefficients		Standardised Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	– 85.423	17.061		– 5.007	0.000
Mean years of schooling (women)	4.961	1.367	0.445	3.630	0.001
Employment rate (women)	0.674	0.107	0.734	6.328	0.000
Recipients of benefits in material need (total population)	1.069	0.278	0.468	3.844	0.000
Other than Slovak nationality (total population)	0.055	0.027	0.145	2.076	0.041
Women in municipalities with 5000+ inhabitants	0.057	0.028	0.197	2.065	0.043

Tab. 3: Multiple linear regression between share of first birth order late fertility in total late fertility in districts of Slovakia and selected indicators, 2015 – 2019 (Model summary: R = 0.860; R Square = 0.739; Adjusted R Square = 0.721). Source: authors' calculations

age for maternal onsets could be related to the existence of a large group of women from disadvantaged backgrounds and with difficulties in job search in the official labour market. According to Friedman et al. (1994), for these women, the early parent role is one of the tools to reduce one's life insecurity. The second important group can be religious women increasing their social status with early motherhood. These women are being influenced by their peer groups and communities to an earlier start of reproduction. A tendency to have a completed family by the age of 35 is very common.

The educational factor was confirmed as a great influence in terms of factors affecting late motherhood in Slovakia. Thus, it is confirmed that the longer women study, the more important their fertility (very often are these just first pregnancies) at the age of 35 and over. Some factors related to the position of women in the labour market (employment rate, employment in the tertiary sector) and wage levels also proved to be important in increasing the share of late fertility and the importance of the first children in reproduction at advanced ages. The degree of female population urbanisation resulted in the same effect. This confirms some of the results of non-ECE studies linking the phenomenon of late motherhood to higher-income workers and the urban population (e.g. Kulu, 2013; Mills et al., 2011; Toulemon, 2005). Some factors that indicate socio-economic problems (unemployment, number of job seekers per one job offer) work in the opposite direction, along with some ethnic variables (proportion of population in Roma settlements). This would suggest that in areas with poorer socio-economic conditions and more frequent representation of people from segregated Roma settlements, an earlier start into motherhood could be a model for reducing life insecurity, subsequently reflected in the parity character of fertility in advanced reproductive ages.

Acknowledgement

This paper was written with funding from VEGA No. 2/0064/20.

References:

ADSERA, A. (2004): Changing fertility rates in developed countries. The impact of labour market institutions. Journal of Population Economics, 17(1): 1–27.

ANDORKA, R. (1978): Determinants of Fertility in Advanced Societes. London: Methuen.

BECK, U. (1992): Risk Society. Towards a New Modernity. London, Sage Publications.

BECKER, G. S. (1981): A Treatise on the Family. Cambridge, Harvard University Press.

BECKER, G. S. (1997): Teorie preferencí. Praha, Dokořán, Liberální institut.

BILLARI, F. C., GOISIS, A., LIEFBROER, A. C., SETTERSTEN, R. A., AASSVE, A., HAGESTAD, G. O., SPÉDER, Z. (2011): Social age deadlines for the childbearing of women and men. Human Reproduction, 26: 616–622.

BILLARI, F. C. KOHLER, H. P., ANDERSSON, G., LUNDSTRÖM, H. (2007): Approaching the Limit: Long-Term Trends in Late and Very Late Fertility. Population and Development Review, 33(1): 149–170.

BEAUJOUAN, É. (2020): Latest-Late Fertility? Decline and Resurgence of Late Parenthood across the Low-Fertility Countries. Population and Development Review, 46(2): 219–247.

BEAUJOUAN, É. (2022): Late fertility intentions increase over time in Austria, but chances to have a child at later ages remain low. Reproductive BioMedicine and Society Online 14: 125–139.

BEAUJOUAN, É., SOBOTKA, T. (2017): Late Motherhood in Low-Fertility Countries: Reproductive Intentions, Trends and Consequences. Vienna Institute of Demography Working Papers, 02/2017.

BEAUJOUAN, É., SOBOTKA, T. (2019): Late childbearing continues to increase in developed countries. Population Societes, 562(1): 1–4.

BERRINGTON, A. (2004): Perceptual postponers? Women´s men´s and couple´s fertility intentions and subsequent fertility behaviour. Population Trends, 117: 9–19.

BLEHA, B., VAŇO, B., BAČÍK, V. [eds.] (2014): Demografický atlas Slovenskej republiky. Bratislava, Geografika.

BLOSSFELD, H.-P., HUININK, J. (1991): Human Capital Investments or Norms of Role Transition? How Women's Schooling and Career Affect the Process of Family Formation. American Journal of Sociology, 97(1): 143–168.

BYNNER, J. (2005): Rethinking the youth phase of life course: The case for emerging adulthood? Journal of Youth Studies, 8(4): 367–384.

DE BEER, J., DEERENBERG, I. (2007): An Explanatory Model for Projecting Regional Fertility Differences in the Netherlands. Population Research and Policy Review 26: 511–528.

DUCHĘNE, J., GABADINHO, A., WILLEMS, M., WANNER, P. (2004): Study of Low Fertility in the Regions of the European Union: Places, Periods and Causes. Eurostat: Population and social conditions 3/2004/F/no.4. Luxembourg, European Commission.

FREJKA, T. (2008): Determinants of Family Formation and Childbearing during the Socieatal Transition in Central and Eastern Europe. Demographic Research, 19(7): 139–170.

FREJKA, T., WESTOFF, C. F. (2008): Religion, Religiousness and Fertility in the US and in Europe. European Journal of Population 24: 5–31.

FRIEDMAN, D., HECHTER, M., KANAZAWA, S. (1994): A Theory of the Value of Children. Demography, 31(3): 375–401.

GAUTHIER, A. H., HATZIUS, J. (1997): Family Benefits and Fertility: An Econometric Analysis. Population Studies 51: 295–306.

HANK, K. (2001): Regional Fertility Differences in Western Germany. An Overview of Literature and Recent Descriptive Findings. International Journal of Population Geography 7: 243–257.

HAKIM, C. (2003): A New Approach to Explaining Fertility Patterns: Preference Theory. Population and Development Review, 29(3): 349–374.

HALÁS, M. (2008): Priestorová polarizácia spoločnosti s detailným pohľadom na periférne regióny Slovenska. Czech Sociological Review, 44(2): 349–369.

HANK, K. (2001): Regional Fertility Differences in Western Germany. An Overview of Literature and

Recent Descriptive Findings. International Journal of Population Geography, 7(4): 243–257.

HAŠKOVÁ, H. (2006): Zkoumání bezdětnosti, jejího růstu a s ním souvisejících sociodemografických jevů v české společnosti v kontextu zemí střední a východní Evropy. In: Hašková, H. [ed.]: Fenomén bezdětnosti v sociologické a demografické perspektivě (pp. 22–58). Praha, Sociologický ústav AV ČR.

HAŠKOVÁ, H., DUDOVÁ, R, POSPÍŠILOVÁ, K. (2019): Kde se berou jedináčci? Faktory související s jednodětností v ČR. Demografie 61(2): 93–110.

CHALOUPKOVÁ, J. (2010): Proměny rodinných a profesních startů. Praha, Sociologický ústav Akademie věd ČR.

JURČOVÁ, D. [ed.] (2010): Populačný vývoj v okresoch Slovenskej republiky 2009. Bratislava, INFOSTAT.

KOHLER, H. P., BILLARI, F. C., ORTEGA, J. A. (2002): The Emergence of Lowest-Low Fertility in Europe during the 1990s. Population and Development Review, 28(4): 641–680.

KOREC, P., MATU, P., ONDOŠ, S., PÁLKOVÁ, P. (2005): Regionálny rozvoj Slovenska v rokoch 1989–2004: Identifikácia menej rozvinutých regiónov Slovenska. Geografika, Bratislava.

KRAVDAL, Ø. (1994): The Importance of Economic Activity, Economic Potential and Economic Resources for the Timing of First Births in Norway. Population Studies, 48(2): 249–267.

KRAVDAL, Ø. (2002): The Impact of Individual and Aggregate Unemployment on Fertility in Norway. Demographic Research 6: 261–293.

KRAVDAL, Ø., RINDFUSS, R. R. (2008): Changing Relationships between Education and Fertility: A Study of Women and Men Born 1940 to 1964. American Sociological Review, 73: 854–873.

KULU, H. (2013): Why Fertility Levels Vary between Urban and Rural Areas? Regional Studies, 47(6): 895–912.

KULU, H., VIKAT, A. (2007): Fertility Differences by Housing Type: The Effect of Housing Conditions or Selective Moves? Demographic Research, 17(26): 775–802.

LESTHAEGHE, R. (1995): The Second demographic transition in Western countries. An interpretation. In: Oppenheim Mason, K., Jensen, A. M. [eds.]: Gender and family change in industrialized countries (pp. 17–62). Oxford, Claredon Press.

McDONALD, P. (2000): Gender equity in theories of fertility transition. Population and Development Review, 26(3): 427–439.

McDONALD, P. (2002): Low fertility unifying the theory and the demography. Demography and Sociology Program. Australian National University.

MIETTINEN, A., ROTKIRCH, A., SZALMA, I., DONNO, A., TANTURRI, M. L. (2015): Increasing Childlessness in Europe: Time Trends and Country Differences. Families and Societes, 33: 1–66.

MILLS, B., BLOSSFELD, H. P. (2005): Globalization, Uncertainty and the Early Life Course: A Theoretical Framework. In: Blossfeld, H. P., Mills, M., Klijzing, E., Kurz, K. [eds.]: Globalization, Uncertainty and Youth in Society (pp. 1–24). London, Routledge.

MILLS, B., RINDFUSS, P. R., McDONALD, P., TE VELDE, E. (2011): Why do people postpone parenthood? Reasons and social policy incentives. Human Reproduction Update, 17(6): 848–860.

POTANČOKOVÁ, M. (2009): Odkladanie do vyššieho veku na Slovensku vo svetle štatistických a kvalitatívnych dát. In: Bleha, B. [ed.]: Populačný vývoj Slovenska na prelome tisícročí kontinuita či nová éra? (pp. 39–61). Bratislava, Geografika.

POTANČOKOVÁ, M. (2011): Zmena reprodukčného správania populácie Slovenska po roku 1989: trendy, príčiny a dôsledky. In: Piscová, M. [ed.]: Desaťročia premien slovenskej spoločnosti (pp. 142–159). Bratislava, VEDA, SAV.

POTANČOKOVÁ, M. (2013): Rodina a životné dráhy mladých dospelých. In: Krivý, V. [ed.]: Ako sa mení slovenská spoločnosť (pp. 89–127). Bratislava, IRIS.

POTANČOKOVÁ, M., VAŇO, B., PILINSKÁ, V., JURČOVÁ, D. (2008): Slovakia: Fertility between tradition and modernity. Demographic Research, 19(7): 973–1018.

PRIOUX, F. (2005): Late Fertility in Europe: Some comparative and historical data. Revue d'Épidémiologie et de Santé Publique-Epidemiology and Public Health, 53(2): 3–11.

SHANAHAN, M. J. (2000): Pathways to adulthood in changing societes: variability and mechanisms in life course perspectives. Annual Review of Sociology, 26: 667–692.

SOBOTKA, T. (2004): Postponement of Childbearing and low Fertility in Europe. Doctoral thesis – University of Groningen. Amsterdam, Dutch University Press.

SOBOTKA, T. (2010): Shifting parenthood to advanced reproductive ages: Trends, causes and consequences. In: Tremmel, J. [ed.]: A young generation under pressure? (pp. 129–154). Berlin Heidelberg, Springer-Verlag.

SOBOTKA, T. (2011): Fertility in Central and Eastern Europe after 1989: Collapse and gradual recovery. Historical Social Research, 36(2): 246–296.

SOBOTKA, T., ADIGÜZEL, F. (2002): Religiosity and Spatial Demographic Differences in the Netherlands (SOM Research Report 02F65). Groningen, University of Groningen.

SOBOTKA, T., BEAUJOUAN, É. (2018): Late Motherhood in Low-Fertility Countries: Reproduction Intentions, Trend and Consequences. In: Stoop D. [ed.]: Preventing Age Related Fertility Loss. (pp. 11–29). Cham, Springer-Verlag.

SLABÁ, J., KOCOURKOVÁ, J., ŠŤASTNÁ, A. (2021): Neplánovaný odklad mateřství do vyššího věku v životní dráze českých žen. Sociológia 53(1): 49–70.

SZALMA, I., TAKÁCS, J. (2012): A gyermektelenséget meghatározó tényezők Magyarországon. Demográfia 55(1): 44–68.

ŠPROCHA, B., BAČÍK, V. (2020): Odkladanie rodenia detí a neskorá plodnosť v európskom priestore. Demografie, 62(3): 123–141.

ŠPROCHA, B., BLEHA, B. (2018): Does Socio-Spatial Segregation Matter? 'Islands' of High Romany Fertility in Slovakia. Tijdschrift voor Economische en Sociale Geografie 109(2): 239–255.

ŠPROCHA, B., FITALOVÁ, A. (2022): Neskorá plodnosť na Slovensku. Sociológia, 54(1): 26–52.

ŠŤASTNÁ, A., SLABÁ, J., KOCOURKOVÁ, J. (2017): Plánování, načasování a důvody odkladu narození prvního dítěte v České republice. Demografie 59(3): 207–223.

ŠŤASTNÁ, A., SLABÁ, J., KOCOURKOVÁ, J. (2019): Druhé dítě – důvody neplánovaného odkladu a časování jeho narození. Demografie 61(2): 44–92.

TOULEMON, L. (2005): Who are the late mothers. Revue d'Épidémiologie et de Santé Publique, 53(2): 13–24.

VAN DE KAA, D. J. (1987): Europe's second demographic transition. Population Bulletin, 42(1): 1–59.

VAN DE KAA, D. J. (1997): Options and Sequences: Europe's Demographic Patterns. Journal of the Australian Population Association, 14(1): 1–30.

VASKOVICS, L. (2001): The sociological theory of post-adolescence. Review of Sociology, 11(1): 5–20.

VIDOVIČOVÁ, L., GREGOROVÁ, E. (2007): Věkové normy v sociologické perspektivě. Sociální studia, 1–2: 201–217.

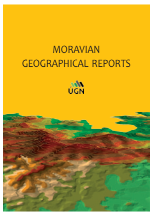
WON HAN, S., BRINTON, M. C. (2022): Theories of Postindustrial Fertility Decline: An Empirical Examination. Population and Development Review 48: 1–28.

ZHANG, L. (2008): Religious Affiliation, Religiosity, and Male and Female Fertility. Demographic Research 18: 233–262.

Please cite this article as:

ŠPROCHA, B., FITALOVÁ, A. (2022): Late motherhood and spatial aspects of late fertility in Slovakia. Moravian Geographical Reports, 30(2): 86–98. doi: https://doi.org/10.2478/mgr-2022-0006

2022, 30(2): 99–115 MORAVIAN GEOGRAPHICAL REPORTS



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics

journal homepage: http://www.geonika.cz/mgr.html

doi: https://doi.org/10.2478/mgr-2022-0007

A geography of creative networks: The case of a small European economy

Vladimír BALÁŽ [a], Tomáš JECK [b]*, Miroslav BALOG [c]

Abstract

This research project analyses the effects of networking by creative and conventional enterprises at regional and inter-industry levels. It relies on a unique dataset provided by the Slovak Creative Voucher Scheme and has some novel elements. We used direct evidence of industry locations from projects developed by creative industries rather than proxies. Network analysis was applied to establish major patterns in regional and inter-industry cooperation by creative and conventional firms. Regression models were used to analyse the network structure. The findings from quantitative analyses were complemented with evidence from qualitative methods. The network included a wide variety of cooperating partners. A sample of creative firms supported by the Creative Voucher Scheme cooperated with partners from no less than 60 industries. Spatial proximity was a key condition for cooperation, enabling face-to-face contacts and the development of a trusting relationship between creative firms and their clients.

Keywords: *creative industries; regional creative networks; inter-industry networks; network analysis; creative vouchers; Slovakia*

Article history: *Received 7 January 2022, Accepted 5 June 2022, Published 30 June 2022*

1. Introduction

Creative industries (DCMS, 1998) are a flourishing sector of the modern economy. These industries have some specific features such as a distinct cultural geography, flexible organisation, use of advanced technologies and extensive employment of creative and technical talent (Lampel and Germain, 2016, p. 2332). The creative industries are both a precondition and an important factor of economic evolution. Entrepreneurship and novelty by creative firms support innovation and creative destruction and the establishment of new products and industries (Potts, 2009). Research on creative industries quantifies their direct and indirect impacts on national and regional economies. Direct impacts relate to growth in employment and value added. Indirect impacts refer to spillovers of knowledge and creativity to the rest of the economy (Potts and Cunningham, 2008; Bakhshi and McVittie, 2009).

This paper provides a new perspective on the role of creative industries in regional economies. It analyses spatial and industrial topologies of the creative industries in the Slovak Republic. The analysis is based on a unique dataset provided by the Creative Voucher Scheme, which supported the formation of partnerships or creative networks between firms from creative industries and conventional ones. We pair information on cooperating partners with data from annual accounts by creative and conventional firms, such as location, business industry and financial indicators. Our research approach is multi-perspective. We combine spatial analysis with network science and qualitative methods.

Our research has some novel elements:

(1) Our focus goes beyond the usual interest in developed economies;

(2) We use direct evidence of industry locations from projects developed by specific creative firms, rather than proxies;

(3) Territorial operations by creative networks are studied both on national and local (LAU 1) levels and combined with firm data;

[a] Institute for Forecasting, Centre of Social and Psychological Sciences, Slovak Academy of Sciences, Bratislava, Slovakia

[b] Institute of Economics, Slovak Academy of Sciences, Bratislava, Slovakia (*corresponding author: T. Jeck, e-mail: *tomas.jeck@savba.sk*)

[c] Faculty of Materials Science and Technology in Trnava, Slovak University of Technology, Trnava, Slovakia

(4) We apply the network analysis to establish major patterns in regional and inter-industry cooperation by creative and conventional firms;

(5) Regression analysis is used to explain the network structure; and

(6) Findings from quantitative analyses are complemented with evidence from qualitative methods (participant survey).

The rest of the paper is organised as follows. In the Chapter 2, the literature review and theoretical background are presented, and the research gap is stated. Based on the literature review and research gap, the research hypotheses are stated. Chapter 3 briefly introduces the Slovak Creative Voucher Scheme, and then it turns to data sources and research methods. Chapter 4 presents findings from the regression analysis and network analyses on regional and industry levels and discusses important outcomes. The same chapter discusses the results of the qualitative analysis. The concluding section summarises the major findings, states some important limitations and suggests directions for further research.

2. Theoretical background

2.1 Literature review

The literature for review was primarily identified based on searches of the Web of Science, Scopus and Google Scholar pages for various keywords (e.g. "creative industries; creative vouchers; creative credits;" AND "networking; geography; region"). The geography of networks in creative industries, network formation and operation, and design and methods used in the research of creative networks, were of prime interest. The literature search aimed at journals and papers focussed on economic and cultural geography, and policy interventions targeting creative industries. In step one, a wide body of papers was established. In step two, a narrow body of influential papers was identified for literature review.

Based on the literature review, this section introduces theoretical foundations of the economic geography of creative industries. It firstly presents major perspectives on locations and clustering by creative industries. Then it turns to some distinctive properties of creative firms and their business models. The concluding part identifies some research gaps and formulates research hypotheses.

A recent literature review on cultural and creative clusters indicated that the most common research themes concerned (Chapain and Sagot-Duvaurou, 2020, p. 323):

i. The impact of territory, innovation milieux and networks on economic value chains; and
ii. Issues of governance and policy evaluation.

Creative firms tend to be highly clustered. The geographical concentration of creative industries is impacted by diverse factors, such as history and cultural heritage, localisation economies, urbanisation economies and a related variety of and decisions by the so-called 'creative class' (Florida, 2005; Lazzeretti et al., 2012, p. 1254). Theories in Economic Geography provide two different, but complementary perspectives on clustering by creative firms. The first perspective originates in Alfred Marshall's (1890, p. 152) ideas on external economies of agglomeration, while the second one relates to Jane Jacob's works (1969) on external economies arising from urbanisation, and innovations related to the diversity of inputs (Lorenzen, 2018, p. 308).

Agglomeration economies, operating on centripetal forces, are behind the distinctive geography of creative industries (Gong and Hassink, 2017, p. 587). Creative industries develop in highly urbanised areas. They usually concentrate around the capitals and/or the largest cities, but regional capitals and medium-sized cities may have their own creative systems specialised in a particular sector or type of creative activity (Boix-Domènech et al., 2016). Large cities attract talent and provide creative firms with a supply of skilled labour. Geographical proximity, extensive service industries, the presence of local institutions, and well-developed infrastructures allow firms to benefit from economies of scale and decrease transaction costs. The stock of skilled labour and transport infrastructures facilitate face-to-face contacts and boost knowledge spillovers. Tao et al. (2019, p. 149), for example, argue that diversity in service industries and availability of transport infrastructure are key factors behind the agglomeration economies of creative industries in China.

The Jacobian perspective (Jacobs, 1969) explains how the conditions created by co-location and the diversity of suppliers and customers create ideal environments for innovations. Clusters of creative industries are co-located and integrated into 'hubs, bunches and clouds' (Boix-Domènech et al., 2015, p. 770). Unlike manufacturing, creative industries rely on inputs of human and social capital rather than fixed investments. Human and social capital are not 'placeless'. Creative activities are always embedded in specific socio-cultural and institutional contexts (Kloosterman, 2010, p. 139) that contribute to different path-dependent trajectories of regional and local creative industries. Localisation decisions by creative firms are spatially grounded (Flew, 2010, p. 88) and informed by opportunities for networking. Creative firms and individuals cluster in specific localities 'for ideas, inspiration and face-to-face communication' (Clare, 2013, p. 56). Huggins and Thompson (2015, p. 104) argue that innovation performance by firms is impacted by their investment in 'network capital', i.e. building relationships with other firms and organisations to 'gain access to knowledge to enhance expected economic returns, principally via innovation'. The co-location provides firms with opportunities for accessing specific suppliers and customers, sharing tacit knowledge, and accumulating collective learning capacities. Collaborative models between traditional and creative firms enable acquiring and combining heterogeneous sources of knowledge and creating innovative solutions (Santoro et al., 2020, p. 6). Advances in transportation, logistic and digital technologies enabled a substantial decrease in transaction costs. Production, sharing and diffusion of knowledge in creative activities, however, is context- and place-specific, and informed by localities, institutions and networks (Watson, 2002, p. 626). Tacit knowledge is embedded in the high-trust local networks of individuals and companies. The spatial costs for accessing localised knowledge and learning, therefore remain high (Morgan, 2004; McCann, 2007).

Businesses in the creative industries have some specific features. The demand for creative goods and services is extremely volatile. Most deals are made case-by-case. Stable customers are the exception, rather than the norm. Daskalaki (2010, p. 1649) argues that repeated creative collaborations are semi-permanent and result in volatile relationships among network members. Volatile business environments are not beneficial for building long-term strategic alliances. The modules of cooperation build upon prior experience. Creative entrepreneurs must form alliances with potential business partners they collaborate with and with whom they can cooperate well in the future (Gundolf et al., 2017, p. 156). Affective bonding and trust are important factors of cooperation in such a volatile environment (Radomska et al., 2019). A recent review of business models in the creative industries suggested emergence of some new trends (Li, 2020, p. 8). There was a transition from using one to several business models by the same firm, so as to sell diverse products and serve different markets. In most cases, the emergence of new business models is about recombining existing rather than introducing radically new ideas. Traditional business models, for example, are scaled up by the introduction of digital technologies. Digital technologies reduce costs and expand a portfolio of potential customers. The digital transformation of creative industries was speeded up by the Covid-19 pandemic (Hassink and Yang, 2021), as both creative firms and their customers had to look for new ways to access their customers.

2.2 The research gap and hypotheses

While there is a rich literature on creative industries, several literature reviews point to certain research gaps. The literature review by Chapain and Sagot-Duvaurou (2020, p. 310), for example, found that as for scale and geographical location, most studies consider either the neighbourhood scale or the city scale. Studies on sub-regional and regional scales are less common. Research on creative industries has rather disproportionally focused on metropolitan regions and specific occupations in cultural sectors (visual and performing arts, fashion, media). Creative industries located in national or regional capitals and/or those based on high technologies, were rather overlooked (Yin and Derudder, 2021). Some influential papers on creative industries have preferred targetting global networking and global capitals (Lorenzen, 2018). Smaller national and regional capitals from Central and Eastern Europe are rather under-represented in studies on creative industries. Studies on public support for creative industries focus on the effects of the support to firms. Research is lacking on the effects of these policies on meso-scale levels, i.e. regional, and inter-industry creative networks. Most research on creative industries looks at collaboration by two or more creative firms. Few studies explore patterns of interaction between creative and conventional firms (but see Santoro et al., 2020). Based on the literature reviews and research gaps, the following research hypotheses were formulated:

- Hypothesis 1: Cooperation by creative and conventional firms is informed by spatial proximity and co-location by creative industries. Proximity and agglomeration effects are more important for cooperation than co-location effects;
- Hypothesis 2: The modularity of the creative network is informed by geography, and the structure of regional economies;
- Hypothesis 3: The capital region develops a countrywide creative network; the regional capitals maintain their own regional networks; and
- Hypothesis 4: Creative networks benefit from repeated collaborations but are volatile.

The hypotheses are based on the review of literature on spatial patterns of creative industries (H1: Marshall, 1890; Florida, 2005; Lorenzen, 2018; Gong and Hassink, 2017; H2: Flew, 2010; Clare, 2013; H3: Boix-Domènech et al., 2016), and collaboration patterns by creative firms (H4: Daskalaki, 2010; Gundolf et al., 2017; Radomska et al., 2019).

3. Data and methods

3.1 The Slovak Creative Voucher Scheme: Intervention logic and implementation

Dynamic markets and the volatility of demand set some constraints for financing firms in the creative industries. The human capital of the owner/manager is often the key asset of a creative firm. Unlike manufacturing enterprises, creative firms have a limited stock of fixed capital to pledge. The asset structure makes it difficult for banks to evaluate the wealth and creditworthiness of creative firms. The public sector may address this market failure via specific support schemes for creative industries.

Many governments provide support to creative industries. Traditional tools of support include grants (Moreton, 2016) and tax incentives (Hemels and Goto, 2017). Creative vouchers (also known as creative credits or creative innovation awards) are a viable option to support creative industries. Several European countries have introduced creative voucher schemes (Shiach and Virani, 2017). Creative vouchers mimic basic properties of innovation vouchers (Virani, 2015): simple rules, easy access for potential applicants and standardised value of support. The key goal of voucher schemes is to bring together prospective partners (Flanagan et al., 2011). The vouchers promote the innovation capacity of small and medium enterprises (SMEs) via networking and the acquisition of external knowledge.

The Slovak Government launched its first national creative voucher scheme in 2018. The Government had noted the relatively low levels of development in the creative industries in Slovakia. The value added to enterprises in the cultural sectors accounted for 1.21% of the total business economy in 2019 (EU27 = 2.40%). In 2019, the share of persons working as creative and performing artists, authors, journalists and linguists in total employment was 0.58% in Slovakia, while it was 0.81% in the EU27 (Eurostat, 2021). Moreover, the shares of creative industries in total value added to the business economy and total employment declined in Slovakia in the period 2011–2019. The Creative Voucher Scheme aimed at 'increasing competitiveness of both SMEs benefitting from creative inputs, and the SMEs in creative industries'. The scheme supported networking for SMEs in creative industries with other enterprises. Four creative industries were eligible for support:

i. Architecture;
ii. Design;
iii. Advertising and marketing; and
iv. Software and information and communications technology (ICT) services.

The vouchers were distributed under the EU *de minimis* legal framework. The minimum value of a voucher was €1,000 and the maximum was €5,000 (€10,000 for architecture services).

The Slovak Innovation and Energy Agency (SIEA) administered the scheme. The SIEA established a matching webpage for SMEs from creative versus conventional industries. Conventional firms applied for a voucher and exchanged it for goods and services provided by creative ones. The scheme generated high interest from creative firms. Some 2,480 firms submitted 3,122 collaborative proposals. The proposals aimed at projects with a total value of €20.08m. Support by vouchers was planned for €14.75m, in the period 2018–2021. Actual support was lower. Some

651 vouchers were distributed to 375 creative firms in the period 2018–2021. The total value of vouchers was €3.564m. The average value of a voucher was €4,585.

3.2 Data sources

We focus on the districts (Local Administrative Units – LAU 1 level) to obtain detailed insights on territorial aspects of networking by creative industries. The Slovak Republic is divided into 79 districts, including five urban districts in Bratislava City and four urban districts in Košice City. In 2022, the average size of a Slovak district was 6,200 km^2 with an average population of 69,000. Nine districts received no support under the Creative Voucher Scheme. We considered Bratislava City and Košice City as whole entities. The regional analysis, therefore, is based on 65 districts. District codes and full names are provided in Appendix Table A2.

Regional economic accounts are available for NUTS 2 and NUTS 3 levels but not for (LAU 1 level) in Slovakia. Some studies use numbers of firms to compute localisation and concentration coefficients. This is problematic given differences in firm sizes. The computation of concentration and localisation coefficients further is complicated by the presence of some large firms in creative industries.

We assume that the location and concentration coefficients should be based on the value that was added rather than the number of firms. The value added is a good proxy for regional and/or sectoral gross domestic product (GDP). We introduce concepts of 'small business economy' and 'creative small business economy' to explore the importance of creative industries on the LAU 1 level. The concepts mirror populations of creative and conventional firms supported by the Creative Voucher Scheme. The 'small business economy' approximates 'business GDP' on national and regional levels via cumulative value added by SMEs in each district. The 'creative small business economy' is a subset of the 'small business economy' for industries supported by the scheme: architecture, design, advertising and marketing, and software and ICT services.

Two major datasets were used to analyse the role of creative firms in regional economies:

1. The first dataset refers to lists of creative and conventional firms supported by the Creative Voucher Scheme. The lists were provided by the SIEA upon request. Descriptive statistics on supported creative and conventional firms are provided in Table 1; and
2. The second dataset was extracted from the FinStat database. The database contained contact details, NACE codes and annual financial statements by all Slovak companies.

3.3 Research methods

Most of the most cited papers on creative clusters explore economic issues, such as value chains (Chapain and Sagot-Duvaurou, 2020, p. 323), but relatively few combined quantitative methods with purely economic or economic geographic perspectives. In contrast, see Tao et al., 2019; Boix-Domènech et al., 2015; and Bakshsi et al., 2015. Sociological and ethnographic perspectives ('relational geography') were the most common approaches in studying sets of formal and informal institutions constituting creative clusters (Harvey et al., 2012; Watson, 2012), structural relationships between cluster members (Daskalaki, 2010; Felton et al., 2015), and the impact of trust on cooperation by network members (Florida, 2005; Radomska et al., 2019). The prevalence of sociological approaches is explained from the higher numbers of case studies and a focus on individual clusters.

The research designs and methods differ widely in studies on the economic geography of creative industries. Many studies are exploratory. As for economic geography, localisation quotients have been widely used as proxies to identify local creative systems (see for example: Boix-Domènech et al., 2016, p. 936). Partial and ordinary least square regression methods have been applied to study determinants of clustering in creative industries (Lazzeretti et al., 2012). Econometric methods were employed to model direct and indirect macroeconomic impacts of creative industries in terms of production and employment (Bakhshi and McVittie, 2009; Boix-Domènech et al, 2021). Finally, several papers have analysed the effects of public support on creative industries. Some authors applied randomised controlled trial settings and sophisticated statistical methods (Bakhshi et al., 2015) to establish the effects of support on firm performance. Studies mapping the effects of support on the formation of creative networks have been missing so far.

	Assets	Equity	Sales	Profits	Value added
			Creative firms		
Mean	162,702	60,432	252,745	23,398	74,022
Median	72,077	25,796	93,080	7,481	27,407
Standard deviation	333,504	122,941	470,716	53,993	135,835
Minimum	3,326	– 197,540	3,556	– 21,943	932
Maximum	2,585,829	750,440	3,374,204	418,982	931,448
			Conventional firms		
Mean	655,954	215,985	561,926	68,061	230,869
Median	174,539	57,844	124,590	23,969	70,831
Standard deviation	1,309,240	467,723	1,300,986	132,727	415,138
Minimum	7,840	– 47,443	130	– 10,495	1,131
Maximum	9,974,802	4,198,810	12,714,100	1,471,481	2,566,733

Tab. 1: Descriptive statistics for participants in the Creative Voucher Scheme (EUR; Note: All values are in Euros and refer to the average of 2016–2019). Source: authors' computations

This paper benefited from a unique dataset on collaboration by creative and traditional firms. Dyadic data on co-operating partners have enabled us to employ network and regression analyses and to explore the importance of creative firms for regional economies. To the authors' best knowledge, this network analysis was used to explore the Economic Geography of creative industries for the first time.

The Creative Voucher Scheme supported both personal businesses and companies (legal entities). Financial data from the FinStat database were available for companies only. The data on value added in the business sector were used to compute concentration statistics (Fig. 1) – location quotients for creative industries (LQ_{ci}) on the LAU 1 levels (Fig. 2). The LQ_{ci} is computed as follows:

$$LQ_{ci} = \frac{d_{VAci}/d_{VAsbe}}{N_{VAci}/N_{VAsbe}}$$

The numerator compares the district's share of value added (VA) in creative industries to the district's value added in the small business economy (sbe). The denominator compares the national share of value added in creative industries to the national value added in the small business economy. An LQ_{ci} higher than 1 means that a district has above-average shares of creative industries with respect to the national average values.

The LQ_{ci} coefficients could be skewed by atypical cases and/or outliers. Firms included in the 'small business economy' and 'creative small business economy' should be commensurable with those participating in the Creative Voucher Scheme. The FinStat database was screened for outliers. The interquartile range (IQR) was used to identify and remove outliers. The scheme supported conventional and creative SMEs. The FinStat samples of 'total economy' and 'total creative economy' included firms with substantially higher values of economic indicators than those supported by the Creative Voucher Scheme. The inclusion of very large firms would bias the LQ_{ci} coefficients. Data from the FinStat database enabled computing these coefficients for 'small business economy' (sbe) and 'creative small business economy.' The original FinStat sample of 228,818 firms was reduced to 159,278 SMEs, including 16,004 creative ones fitting the value:

$$sbe_{ij} < max[c_{i,j}] + 0.25 * SD[c_{i,j}],$$

where the sbe_{ij} is the value of the j-th indicator of the i-th firm in the small business economy sample, $max[c_{i,j}]$ is the maximum value of the j-th indicator of the i-th firm in the respective conventional and creative firm samples and SD is the standard deviation. The final dataset approximated 'small business economy' and creative small business economy,' respectively, on the LAU 1 levels.

Figure 1 shows the percentage shares of specific districts in the national creative small business economy. Bratislava City represents a concentrated 52.1 and Košice City 7.4 percent of the total value added. The high concentration of creative industries suggested strong agglomeration effects for the Bratislava Region. The same pattern emerged for the co-location effects – the Bratislava Region accounted for the highest location quotients (Fig. 2). Figures 3 and 4 present the distribution of voucher support by regions of conventional and creative firms, respectively. Most of the support by vouchers was concentrated in regions with a high concentration of creative industries and/or high location quotients.

4. Results and discussion

4.1 Regression analysis

Ordinary linear regression models are used here to explain the geographical structure of the creative networks. Pairs of creative versus conventional firms are the unit of analysis. The value of vouchers transferred from conventional firms in region a ('target region') to creative firms in region b ('source region') is the dependent variable. The choice of explanatory variables was based on assumptions from geographic research on the effects of distance and location on cooperation patterns. We assumed that conventional firms would prefer creative partners coming from close districts and/or those specialised in creative industries.

We first produced statistics on location by creative industries. We then considered the physical distance between the regions of the creative and conventional firms. When the creative and conventional firms came from the same region,

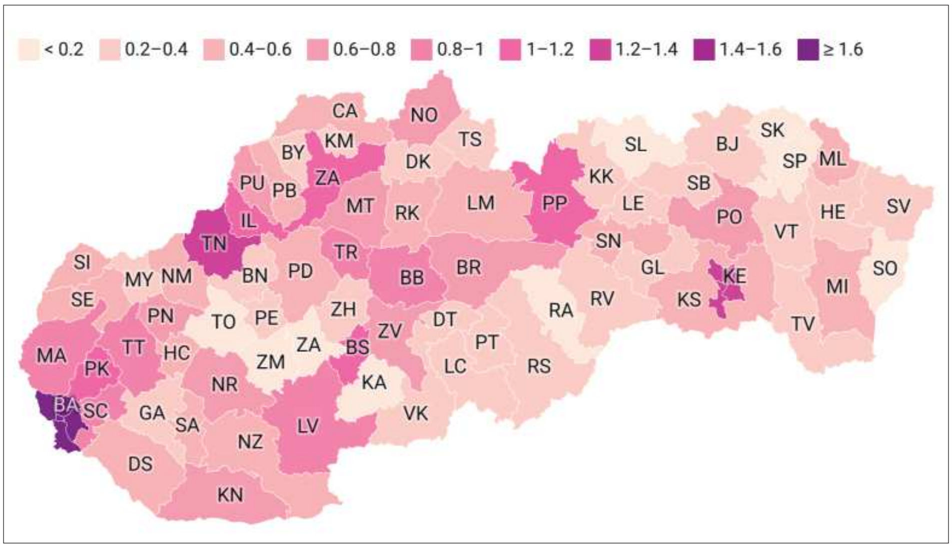


Fig. 1: Percentage shares of specific districts in the national creative small business economy
Source: authors' elaboration

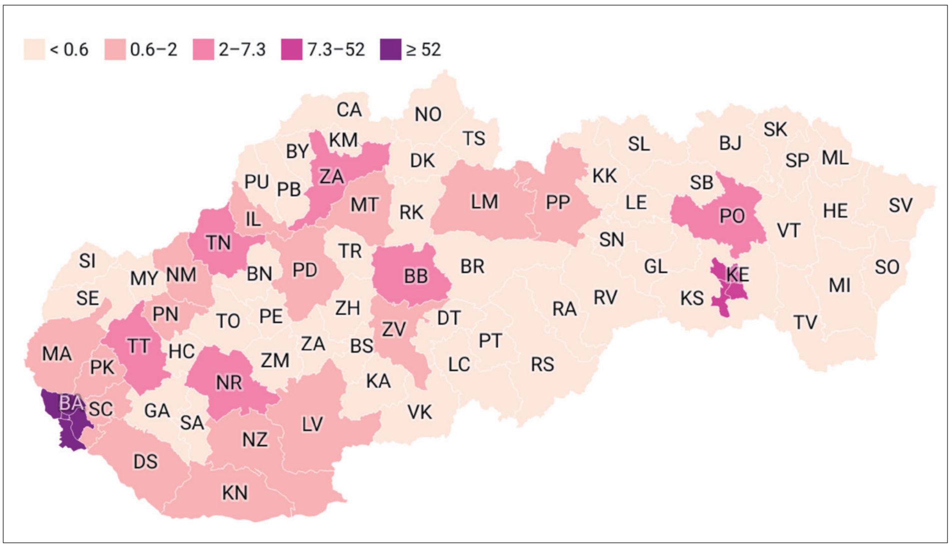


Fig. 2: Regional location quotients for creative industries
Source: authors' elaboration

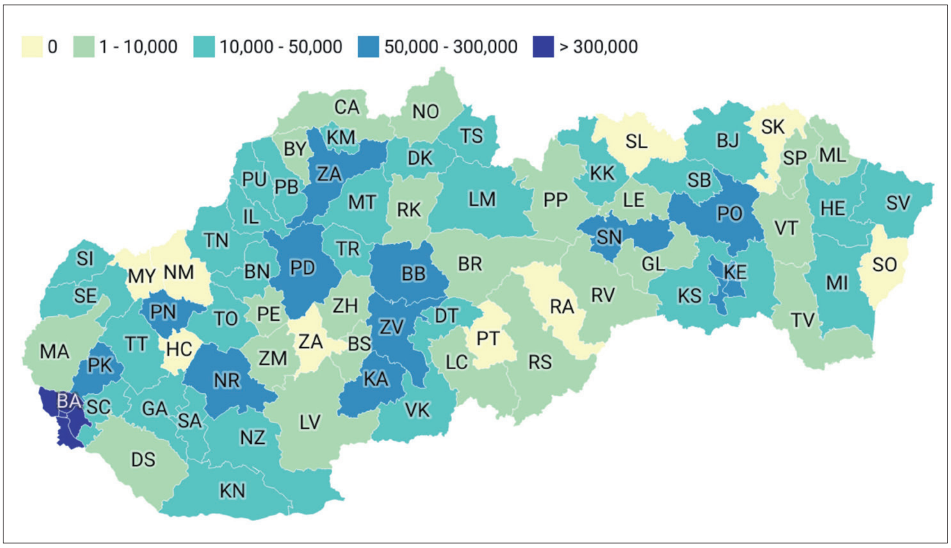


Fig. 3: Voucher support by region of conventional firms (EUR)
Source: authors' elaboration

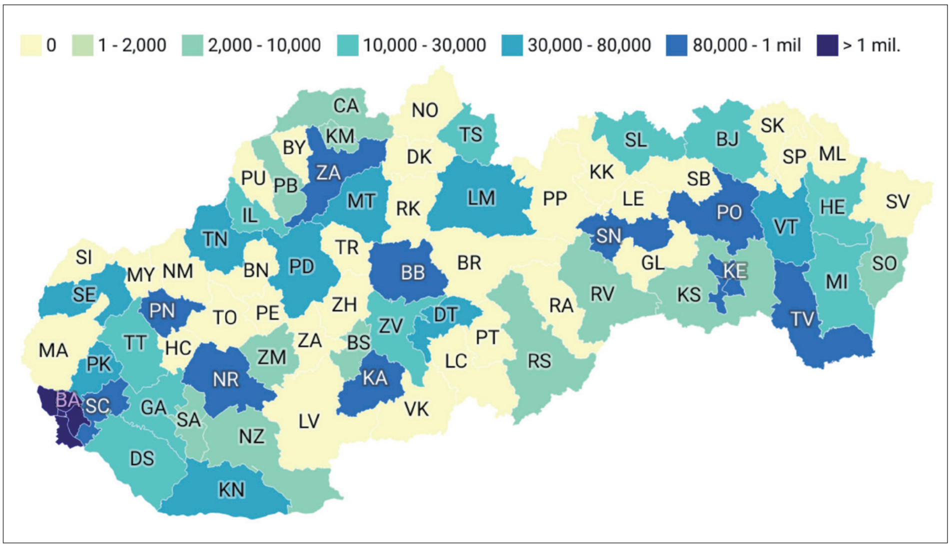


Fig. 4: Voucher support by region of creative firms (EUR)
Source: authors' elaboration

we specified a distance of 1 km. All variables had non-linear distributions, hence we used natural logs for variables on both sides of the model.

The regression analysis confirmed that distance was negatively, and the location quotient positively related to the sum of creative vouchers transferred from conventional to creative firms (Tab. 2). The variance inflation factor (VIF) statistics indicated no potential problems with collinearity. Both independent variables were significant on the 0.001 levels. The standardised Beta coefficient for distance was substantially higher than that for the location quotient. This suggests that short distance was more important for the formation of creative networks than co-location of creative industries in specific regions (Hypothesis 1 confirmed). While digital products accounted for a substantial part of the co-operation by the traditional and creative firms under the Creative Voucher Scheme, there was no 'death of geography' (Morgan, 2004). Spatial proximity and opportunities for face-to face contacts were important determinants of collaboration.

4.2 Network analysis

Economic geography assumes co-location and clustering by creative firms in urbanised and metropolitan areas (Florida, 2005; Boix-Domènech et al., 2015). We applied network science (Easley and Kleinberg, 2010) to map and analyse inter-industry and spatial networks by creative and conventional firms (see Figs. 5 and 6). The networks are constructed from nodes (depicted by circles) and edges (represented by curved lines). The nodes represent specific districts and industries, respectively. Districts are denoted by their national codes and industries by the standard NACE codes. The district code BA, for example, denotes Bratislava City, while the node code J62 refers to the computer programming industry. Node size ('degree') is then computed as the sum of its connection to other nodes weighted by edge thickness. Two types of degrees are recognised: the weighted indegree is identical to the size of weighted inflows, while the weighted outdegree is identical to weighted outflows from the node. Node sizes correspond with the sum of vouchers received by conventional firms in specific regions or industries (the 'weighted indegree' perspective). The largest node in Figure 6, for example, represents all vouchers received by Bratislava City-based conventional firms (€1.003m). Similarly, the edge thickness represents the size of the flow, i.e. the value of vouchers exchanged among pairs of districts or industries. The thickest (green) line in Figure 5, for example, denotes vouchers (€0.177m) provided by the J62 computer industry to the G47 retail industry.

	B	Std. Error	Beta	t	sig	VIF
(Constant)	10.112	0.144		69.991	0.000	
LN distance in km	– 0.252	0.031	– 0.477	– 8.257	0.000	1.000
LN location quotient for source region	0.320	0.074	0.249	4.306	0.000	1.000
Adjusted R squared = 0.281; SEE = 0.739; sig. 0.000						

Tab. 2: Regression analysis (log-log linear model). Source: authors' computations
*Note: Dependent variable: natural log of vouchers exchanged between conventional firms from region **a** to creative firms in region **b***

Complex networks may be divided into specific modules (communities or clusters). The modules are defined as groups of densely interconnected nodes that have relatively few or no connections with the rest of the network. Figures 5 and 6 display modules of cooperation by creative and conventional firms from the industry and spatial perspectives, respectively. Gephi software was used to produce the network diagrams. Two force-directed algorithms (Fruchterman-Reingold and Force Atlas 2) were applied to arrange nodes to specific geographic and industry modules (Jacomy et al., 2014).

We first analyse inter-industry networks of cooperation. Then we turn to the regional networks. Finally, we combine the inter-industry and regional data to analyse creative networks by specific regions.

4.2.1 Inter-industry creative networks

Industries in cooperation modules are identified by their respective NACE codes on the two-digit level. Five distinctive modules emerged in the industry network diagram (Fig. 5):

1. The largest (blue) module distributed support €1.146m to 19 industries. The module interconnected industries F41 (construction of buildings), G46 (wholesale trade), L68 (real estate), M70 (management consultancy), M71 (architectural and engineering activities) and many small manufacturing industries;
2. The second largest (green) module contained 16 industries and distributed support (€0.896m). The module centred on the J62 industry (computer programming) and included very diverse manufacturing and service activities, such as F43 (specialised construction activities), G45 (sale and repair of motor vehicles), S96 (other personal services), and many more;
3. The third largest (violet) module included 17 industries and distributed support €0.711m. The module centred on industries G47 (retail trade), M73 (advertising), M74 (other professional, scientific, and technical activities). It included several service and manufacturing industries;
4. The orange module comprised six industries (€0.271m). The module connected industries M69 (legal and accounting activities) and N82 (office administrative) with four other small service and manufacturing industries; and
5. The minor dark green module consisted of two industries only: K64 (financial service activities), and K66 (activities auxiliary to financial services). This module distributed €0.018m in support.

Most modules referred to the vertical integration of industries. The blue module, for example, integrated architecture, construction, real estate, and management consultancy. The green module, on the other hand, reflected horizontal service inputs by the computing programming industry to the rest of the economy. The modules typically showed a great diversity of manufacturing and service industries. The cooperation across sectors provided fertile ground for inter-industry knowledge spillovers.

4.2.2 Regional creative networks

The Slovak creative firms clustered in urbanised areas. Firms located in Bratislava City and the regional (NUTS 3) capitals benefitted from location and urbanisation economies. Spatial patterns of location and networking by creative firms in Slovakia resembled those in Western Europe (Branzanti, 2015; Boix-Domènech et al., 2016). Large cities accounted for the highest presence of creative industries (Fig. 6). The SMEs located in the largest cities had the highest participation in the Creative Voucher Scheme. By far the highest share of the total cooperation was concentrated in Bratislava City. Some 33.0 percent of total voucher support,

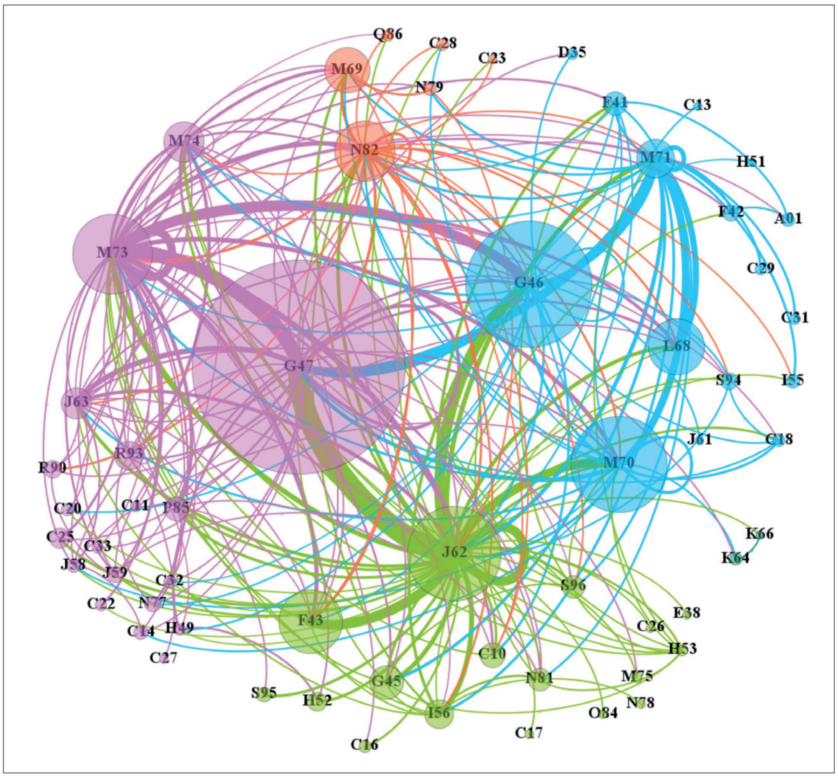


Fig. 5: Industry patterns of cooperation by creative and conventional firms
Source: authors' elaboration of NACE standard industry codes

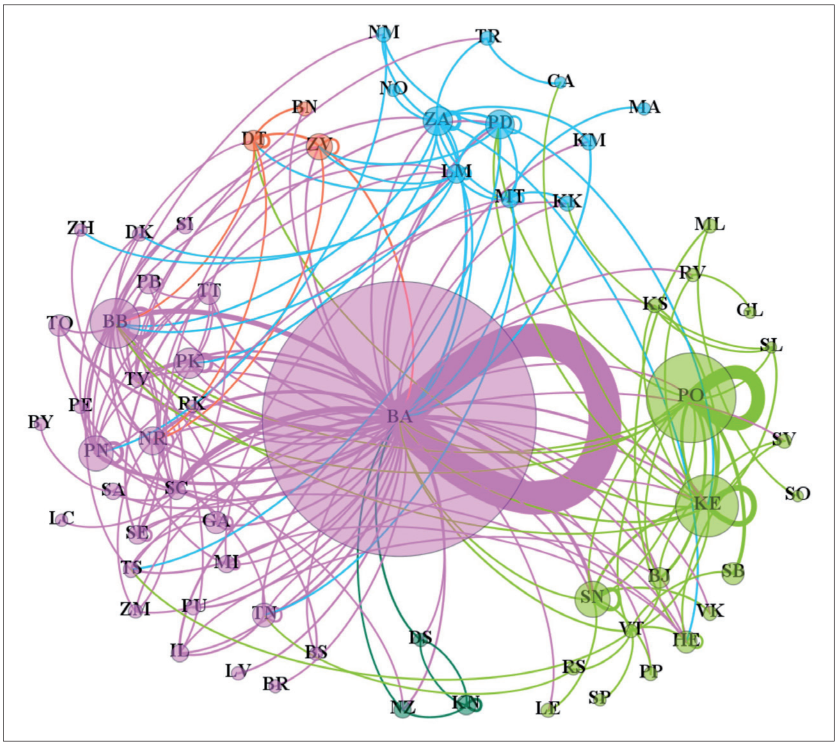


Fig. 6: Regional patterns of cooperation by creative and conventional firms
Source: authors' elaboration of district codes

for example, was received by companies in Bratislava City. Some 21.2 percent of the total support went to cases in which both creative and conventional firms came from Bratislava City. The situation is depicted by a distinctive loop-like flow in Figure 6. Similar albeit much smaller loops operated in Košice City and the Prešov region.

Geographical network analysis established five modules of cooperation. All five modules had distinctive regional dimensions:

1. Module 1, the largest (violet) module, included 29 districts and centred around Bratislava City (BA) and some regional and districts capitals. The module distributed support totalling €1.810m.;
2. Module 2, the second largest (green) module, included 19 districts in eastern Slovakia. It connected two regional capitals (Košice City and Prešov) with 17 smaller districts. The module distributed support totalling €0.801m.;
3. Module 3, the blue module, centred on the regional capital of Žilina (ZA) in northern Slovakia. The module connected 11 districts in total and distributed support totalling €0.262m.;
4. Module 4, the orange module, comprised three small districts in central Slovakia and distributed support totalling €0.107m.; and
5. Module 5, the dark green module, connected three district capitals in southern Slovakia. The districts had high proportions of the Hungarian-speaking population. The module distributed support totalling €0.064m.

The clustering of districts in specific modules was influenced by the physical distance and structure of regional economies. Module 1 centred on the highly urbanised and services-based economy of Bratislava City. Modules 2 and 3 focused on urbanised regional and district capitals with mixed service- and manufacturing-based economies. Modules 4 and 5 centred on semi-urbanised small district capitals with manufacturing-based economies. The formation of Module 5 was informed by the culture and language of the Hungarian minority population.

4.2.3 Regional patterns of inter-industry cooperation

Table 3 analyses the top ten industries benefitting from voucher support, by specific regional modules. The scheme supported creative firms in architecture, design, advertising and marketing, and software services. Products and services by creative firms (e.g. e-shops, webpages, showrooms, marketing campaigns and industrial designs) were used as intermediary inputs in regional economies. The conventional firms in the industries G46, G47, M70, M73 and M74 were major clients of the scheme and featured prominently in all regional modules. Each regional module, however, had its own composition of benefitting industries (Hypothesis 2 confirmed). Highly urbanised regions of Bratislava and Košice City and urban regions in northern Slovakia channelled most support by vouchers to service industries. The semi-urban regions in central and southern Slovakia (Modules 4 and 5) accounted for higher shares of manufacturing industries (such as C10, C11, C14, C23, C33) in their economies. Manufacturing firms featured as important clients of creative firms in Modules 4 and 5.

Our research findings agree with the findings by Cruz and Teixeira (2015, p. 173) that creative industries tend to agglomerate in limited numbers of locations, but geographical patterns differ by location and specific type of creative activity.

4.2.4 Centrality measures

The centrality measures identify positions of specific nodes within a network. Centrally located nodes are more important for the whole network than those located on the periphery. Over two hundred centrality measures have been proposed by researchers in network science (Jalili et al., 2015; Oldham et al., 2019). The most popular measures include closeness centrality and betweenness centrality.

Closeness centrality measures the speed of information spread, i.e. how many steps it takes from one specific node to all other nodes sequentially. Personal recommendation by a trusted source, rather than unreliable information acquired via several intermediate sources, is important in small

Total Slovakia	%	**Module 1 (Bratislava)**	%	**Module 2 (eastern Slovakia)**	%	**Module 3 (northern Slovakia)**	%	**Module 4 (central Slovakia)**	%	**Module 5 (southern Slovakia)**	%
G47	16.96	G47	14.92	G47	18.08	G47	27.64	G47	17.61	G47	17.82
G46	9.80	G46	9.69	G46	9.03	G46	12.01	F43	12.24	M74	15.06
M70	7.37	M70	8.56	J62	6.54	M70	9.49	G46	11.41	N82	12.23
J62	7.18	J62	7.72	F43	6.21	J62	7.93	C14	8.72	G46	10.29
M73	6.01	M73	6.41	M73	5.40	M73	7.02	L68	8.42	J62	7.86
F43	4.69	L68	4.86	M71	5.08	N82	5.13	C11	8.16	M73	7.23
N82	4.41	F43	3.95	N82	4.97	L68	4.48	M70	4.64	C10	6.37
L68	4.03	N82	3.95	M70	4.72	F43	3.63	M71	4.57	C23	6.03
M69	3.14	M69	3.23	I56	3.45	M69	3.24	E35	4.54	F41	6.02
M74	2.75	J63	2.93	M69	2.99	Q86	2.18	C33	4.31	I56	4.29
Top 10	**63.33**	**Top10**	**66.20**	**Top10**	**66.48**	**Top10**	**82.76**	**Top10**	**86.64**	**Top10**	**93.20**

Tab. 3: Regional patterns of inter-industry of cooperation
Source: authors' computations

businesses. A wholesale trader with hundreds of suppliers and customers is an example of a firm high in closeness centrality within the network. Betweenness centrality measures the extent to which a node lies on paths between all other nodes. Nodes high in betweenness centrality may interconnect remote modules and act as gatekeepers and/or brokers in the network. A creative firm, for example, could specialise in the marketing of food products, but it wishes to expand its business to the marketing of tourism products. An option is to contact its former client, a web hosting firm that is doing business with many diverse industries. The web hosting firm is an example of a node high in betweenness centrality. Specific centrality measures are not mutually exclusive. One firm may combine several or all centrality measures.

The centrality measures perform differently in highly connected versus highly modular networks (Oldham et al., 2019, p. 9). If all nodes are connected to many other nodes, then most nodes are likely high in the closeness centrality measure. The situation is different with highly modular networks, such as the regional and inter-industry networks of the Slovak creative firms. Many nodes high in closeness centrality have dense connections with other nodes inside their own module, but relatively sparse connections with nodes in other modules. This is the case of the Slovak regional networks of cooperation (Fig. 6). Nodes high in betweenness centrality, on the other hand, have numerous connections to nodes in other modules.

High scores in closeness and betweenness centrality may indicate some potential for recombining knowledge from diverse regions or industries. Regions (industries) high in closeness centrality may be important for the transfer of knowledge within a specific region (industry). Nodes high in betweenness centrality may be influential for inter-regional and/or inter-industry sectoral knowledge transfer. It should be noted that a high score in closeness and betweenness centrality is necessary but not a sufficient precondition for generating substantial knowledge transfer. The number of available resources (e.g. volume of business) equally is important for the propagation of knowledge through the network. We measure the amounts of available resources by the weighted indegree, i.e. the total amount of creative vouchers amassed by a region (industry). Regions and industries high in closeness and betweenness centrality and weighted indegree likely have major potential for knowledge spill overs (see Appendix Tabs. A1 and A2).

Unsurprisingly, Bratislava City featured a combination of the highest closeness and betweenness centralities and weighted indegree. The surprising feature is the sheer dominance of the Slovak capital over the whole network, given Bratislava's eccentric location in the southwest of the country and moderate population (eight percent of the total Slovak population). The regional capitals (Trnava, Trenčín, Nitra, Žilina, Banská Bystrica, Košice City and Prešov) displayed high closeness centralities, but quite low betweenness centralities (Appendix Tab. A2). In other words, the regional capitals were influential only within their own regional modules but relatively unimportant for the whole network. Only Bratislava City has developed dense connections across the whole country (Hypothesis 3 confirmed). It indicates that the Bratislava-centred module substantially benefitted from agglomeration effects and external economies of scale, i.e. a rich supply of skilled labour, well-developed communication infrastructure and proximity to institutions of national importance (government, universities, large suppliers). These findings resonate with those by Tao et al. (2019). At the same time, the Bratislava-centred cluster profited from co-location effects, i.e. the opportunities for networking, and accessing and sharing tacit knowledge.

As for the inter-industry network of cooperation, the computer programming (J62), retail (G47), wholesale trade (G46) and market research and advertising (M73) industries featured combinations of high closeness and betweenness centralities and weighted indegree. Computer programming accounted for a major turnover in voucher flows (measured by combined weighted indegrees and outdegrees) and profiled as a major hub and central industry for the whole network (as indicated by the highest values of the betweenness centrality measures, Appendix Tab. A1).

4.3 Evidence from qualitative research

We applied a mixed methods approach to obtain a more in-depth understanding of the creative networks. The quantitative analysis was complemented by qualitative research.

We approached the Slovak Ministry of Economy (parent organisation of the SIEA) and asked for a list of scheme participants and their contact details. We first conducted a small number of pilot interviews with creative and conventional firms. We were interested in whether they had already cooperated in the past and how this cooperation impacted participation in the scheme. The interviews indicated that previous personal experience was central for matching. The SIEA webpage was intended to provide a matching place for creative and conventional firms. The web portal, however, proved less important, while geographical proximity, the opportunity for face-to-face contacts and satisfaction with former cooperation, were essential for networking under the Creative Voucher Scheme.

The pilot interviews informed the questionnaire surveys for creative and conventional firms. The surveys addressed two topics:

1. Motivation for participation in the scheme and benefits of cooperation in the scheme; and
2. Patterns of past and future cooperation.

The first topic was addressed by short verbal protocols (SVP) and the second by 'yes/no' statements. The participant survey was implemented in June 2021. Some 124 conventional and 44 creative firms provided their responses. The structure of responses is summarised in Table 4. The geographical structure of responses followed the actual distribution of support: some 35.0% conventional

Sample	manager	owner	owner / manager	employee
Conventional firms; N = 124	14.5	13.7	57.3	14.5
Creative firms; N = 44	4.0	25.0	65.9	4.5

Tab. 4: Structure of survey respondents (%)
Source: author's survey

Plans for future co-operation	no	yes	total
	Conventional firms (N = 124)		
We have already co-operated before	36.3	23.4	59.7
This was our first-time co-operation	23.4	16.9	40.3
	Creative firms (N = 44)		
We have already co-operated before	34.1	22.7	56.8
This was our first-time co-operation	22.7	20.5	43.2

Tab. 5: History of cooperation and plans for future cooperation (%)
Source: authors' survey

and 40.1% creative firms came from the Bratislava region. The scheme mostly connected established partners. Some 59.7% of conventional firms confirmed previous cooperation with creative firms and 40.3% indicated plans for future cooperation (see Tab. 5).

The business of creative firms was significantly more volatile than that of conventional firms. We asked the SIEA for a list of supported firms. We then paired the list with financial accounts of supported enterprises. Creative firms accounted for much lower mean assets and sales than conventional ones (Tab. 1). Creative firms were the more vulnerable and proactive parties in the cooperation. Some creative firms persuaded as many as ten conventional ones to cooperate. Creative firms framed their motives for participation differently from conventional ones.

Cost-cutting in marketing and presentation was the most frequent motive for conventional firms to participate in the Creative Voucher Scheme. One firm commented:

> "We planned investment in marketing and presentation of the firm on the web. The scheme helped to pay for a good quality webpage".

Another firm noted:

> "We own a small network of private pharmacies. We wanted to unify their presentation to increase awareness of our network by customers".

A smaller number of conventional firms mentioned product and process innovations:

> "We aimed at improving intra-firm communication skills" and "We promoted our new product on the market".

Creative firms acknowledged cost-cutting intentions by their clients. One creative firm commented:

> "Most of our customers are price sensitive. The voucher pays for their creative expenditure, which would not happen otherwise".

Another creative firm confirmed:

> "It was a great opportunity for the clients to implement their projects at a discount price".

Creative firms considered the Creative Voucher Scheme an opportunity to engage in more complex projects. A webpage or digital marketing were typical products provided to partners. The creative firms wanted to go beyond the typical 'order and pay' relationship. They wished to build stable relationships with their customers. One creative firm noted:

> "There are some demanding projects with uncertain returns. We were able to do the project with existing clients only via the voucher scheme. It was a new opportunity to develop business relations".

Two other firms commented:

> "The client liked the voucher – it paid for 50% of the costs. The same client later commissioned more demanding projects with us" and "Some clients wanted to order more complex product packages but lacked money. The voucher helped to pay some costs".

The interviews indicated that creative firms flexibly adapted their business models to offer diverse products to specific clients. Most products referred to digital marketing, and recombined existing rather than introduced new ideas. These findings resonate with those by Li et al. (2008). Digital products enhanced internal economies of scale by the creative firms and helped to expand their client base (Lorezen, 2018).

The creative firms hoped to deepen their trust-based relations and approached their clients with above-standard services. The Creative Voucher Scheme distributed relatively low support but accounted for substantial administration. One conventional firm complained:

> "We were really glad to participate in the scheme, but the administrative burden was significant. Reference manuals were barely comprehensible. We had to rework our application three times, and it took one and a half years to be reimbursed for the voucher".

The administrative burden made many conventional firms hesitant about applying to the scheme. Some creative firms helped their partners to navigate complex procedures to get the cooperation done. Creative firms, for example, filled application forms and communicated with the SIEA in the name of their clients. Close cooperation was possible only via the parties' mutual knowledge and trust.

The above-standard trust-based relations and the history of former cooperation, however, did not necessarily result in permanent cooperation patterns. Some 59.7% of conventional and 56.8% of creative firms did not plan to cooperate with their project partners in the future (Tab. 2). Hence, cooperation by creative and conventional firms was opportunity-based. This finding supports Daskalaki's (2010, p. 1659) propositions about the semi-permanent but volatile nature of networks in creative industries. The survey results provide some support for Hypothesis 4.

5. Conclusions, limitations, and directions for further research

The Creative Voucher Scheme provided a unique opportunity to explore the operations of creative networks on regional and industry levels. Key findings relate to the geography of creative networks.

This research contributes to the understanding of agglomeration and co-location effects on development by creative industries. Prior research, for example, measured co-location effects indirectly, via location quotients for creative firms (Boix-Domènech et al., 2016). Dyadic data on projects by creative and traditional firms enabled more direct measures of co-operation. The network analysis revealed a distinctive core-periphery structure of the network, with the core identical with Bratislava City and the rest of the country as the periphery. The results of the network analysis are supported by those from the regression model: the Beta coefficient for distance from Bratislava was about twice the value as that for location. Results from the network analysis and qualitative research suggested that agglomeration effects and spatial proximity were key for business success. Proximity decreased transport costs and enabled face-to-face contacts and the development of a trusting relationship between creative firms and their clients (Gundolf et al., 2017; Radomska et al., 2019). The module membership was informed by spatial factors, and in the case of the fifth module, by language and cultural proximity. Short-haul partnerships were much more common than long-haul ones. Most creative firms originated in the computer programming industry and could access their clients online. They preferred trusted partners, however, whom they knew and could meet in person. Our findings that creative industries clustered in the capital region and several regional capitals confirm assumptions of agglomeration theory (Gibson and Kong, 2005). The central position of digital technologies in cooperation networks meant no 'death of distance' (Morgan, 2004). On the contrary, most networking happened on local and regional levels.

As for the co-location effects, the network analysis indicated that each regional cluster (module) had its own structure of inter-industry cooperation. The finding supports propositions by Cruz and Teixeira (2015, p. 174) and Yin and Derudder (2021, p. 9) about the presence of diverse cultural economies in smaller or peripheral cities. The Creative Voucher Scheme fostered dense and diverse creative networks. The sample of creative firms supported by the scheme cooperated with partners from no less than 60 industries. Substantial diversity of cooperating industries created opportunities for mutual learning, exchange of ideas and development of product, process, and marketing innovations (Jacobs, 1969).

Creative industries accounted for relatively minor shares in total regional economic outputs. Creative firms had to tailor their products and services to the incumbent structure of regional economies. Cooperation with conventional firms supported embeddedness by creative industries with respect to regional and local economies. The computer programming industry was a key facilitator of inter-industry cooperation in all regional modules. It contributed to the digitalisation of regional economies and boosted their resilience to technology shocks. These findings have important policy implications. The Creative Voucher Scheme seems a promising low-cost candidate for policies aimed at increasing the sophistication and embeddedness of regional economies.

Our research has some limitations concerning sample size and period of analysis. The sample of creative firms and their beneficiaries was large and well-structured in terms of industry and regional distribution. The support scheme, however, supported only four sectors of creative industries. Therefore, we do not claim the sample was representative of all creative industries and their partners in Slovakia. The sample refers to firms supported in 2019. Our research, therefore, provided a picture of inter-industry and regional creative networks in the last 'normal' year before the pandemic. The impact of the pandemic on creative firms has been strong but uneven across sub-industries. Lockdowns and other restrictive measures have impacted some firms more than others. Firms active in architecture and design, for example, have struggled to find clients, while ICT firms have benefitted from the rapid transition to the digital economy during the period.

Limitations in this work suggest directions for further research. The most intriguing question concerns the long-term impacts of the Creative Voucher Scheme on cooperation between creative firms and conventional ones. Structural economic transformation, speeded by the pandemic, increased demand for specific digital creative services. We would expect the ICT-based creative firms to expand and diversify their business across the regional economies. Follow-up research on firms supported by the voucher may improve our understanding of evolution by creative networks. Interviews with supported firms suggested that cooperation projects developed mostly between established partners. The question is how resilient this cooperation is to major external events such as pandemics and technology transition.

Flows of knowledge between and across regions, industries and firms is an important precondition of regional growth (Huggins and Thompson, 2014). The theory of recombinant growth proposes that technological advancement and economic growth do not rely primarily on the creation of new ideas, but on repurposing existing ones (Weitzman, 1998, p. 333). The theory suggests that existing ideas can be reconfigured in new ways to make new ideas. The degree of innovation is determined by the relatedness and diversity of recombined knowledge (Antonelli et al., 2010; Battke et al., 2016). Studies of inter-industry cooperation suggest that a recombination of closely related technologies results in more incremental innovations, while a high degree of unrelated variety (the recombination of very different ideas and technologies) may result in higher shares of breakthrough innovations (König et al., 2010). Follow-up research may explore whether the supported firms become more innovative and/or competitive over time. Data from the national patent office, for example, may help to identify firms applying for patents, trademarks, and industrial designs. The FinStat database enables monitoring of changes in financial indicators (e.g. sales, value added, profits) over time by supported firms. Both databases are well designed for longitudinal research, essential for research on economic evolution.

Acknowledgments

This research was supported by VEGA Grant No. 2/0001/22 and VEGA Grant. No 2/0097/19.

References:

ANTONELLI, C., KRAFFT, J., QUATRARO., F. (2010): Recombinant Knowledge and Growth: The Case of ICTs. Structural Change and Economic Dynamics, 21(1): 50–69.

BAKHSHI, H., MCVITTIE, E. (2009): Creative supply-chain linkages and innovation: do the creative industries stimulate business innovation in the wider economy? Innovation: Organization & Management, 11(2): 169–189.

BAKHSHI, H., EDWARDS, J. S., ROPER, S., SCULLY, J., SHAW, D., MORLEY, L., RATHBONE, N. (2015). Assessing an experimental approach to industrial policy evaluation: Applying RCT+ to the case of Creative Credits. Research Policy, 44(8): 1462–1472.

BATTKE, B., SCHMIDT, T. S., STOLLENWERK, S., HOFFMANN, V. H. (2016): Internal or external spill overs – which kind of knowledge is more likely to flow within or across technologies. Research Policy, 45(1): 27–41.

BOIX-DOMÈNECH, R., HERVAS-OLIVER, J., MIGUEL-MOLINA, B. D. (2015): Micro-geographies of creative industries clusters in Europe: From hot spots to assemblages. Papers in Regional Science, 94(4): 753–777.

BOIX-DOMÈNECH, R., CAPONE, F., DE PROPIS, L., (2016): Comparing creative industries in Europe. European Urban and Regional Studies, 23(4): 935–940.

BOIX-DOMÈNECH, R., MOLINA, B. D., KÖSTER, P. (2021): The impact of cultural and creative industries on the wealth of countries, regions, and municipalities. European Planning Studies, 1–21.

BRANZANTI, C. (2015): Creative clusters and district economies: Towards a taxonomy to interpret the phenomenon. European Planning Studies, 23(7): 1401–1418.

CHAPAIN, C., SAGOT-DUVAUROUX, D. (2020): Cultural and creative clusters – a systematic literature review and a renewed research agenda. Urban Research & Practice, 13(3): 300–329.

CLARE, C. (2013): The essential role of place within the creative industries: Boundaries, networks, and play. Cities (34): 52–57.

CRUZ, S. S., TEIXEIRA, A. A. C. (2015): The neglected heterogeneity of spatial agglomeration and co-location patterns of creative employment: evidence from Portugal. The Annals of Regional Science, 54(1): 143–177.

DASKALAKI, M. (2010): Building 'Bonds' and 'Bridges': Linking Tie Evolution and Network Identity in the Creative Industries. Organization Studies, 31(2): 1649–1666.

DCMS (1998): The creative industries mapping document. DCMS, London.

EUROSTAT (2021): Data on the cultural sector [online]. Available at: https://ec.europa.eu/eurostat/web/culture/data/database

EASLEY, D., KLEINBERG, J. (2010): Networks, crowds, and markets reasoning about a highly connected world. Cambridge, Cambridge University Press.

FLANAGAN, K., UYARRA, E., LARANJA, M. (2011): Reconceptualising the 'policy mix' for innovation. Research Policy, 40(5): 702–713.

FELTON, E., COLLIS, C., GRAHAM, P. (2010): Making Connections: creative industries networks in outer-suburban locations. Australian Geographer, 41(1): 57–70.

FLEW, T. (2010): Toward a Cultural Economic Geography of Creative Industries and Urban Development: Introduction to the Special Issue on Creative Industries and Urban Development. The Information Society, 26(2): 85–91.

FLORIDA, R. (2005): Cities and the Creative Class, New York, Routledge.

GIBSON, C., KONG, L. (2005): Cultural economy: A critical review. Progress in Human Geography, 29(5): 541–561.

GONG, H., HASSINK, R. (2017): Exploring the clustering of creative industries, European Planning Studies, 25(4): 583–600.

GUNDOLF, K., JAOUEN, A., GAST, J. (2018): Motives for Strategic Alliances in Cultural and Creative Industries. Creativity and Innovation Management, 27(2): 148–160.

HARVEY, D. C., HAWKINS, H., THOMAS, N. J. (2012): Thinking creative clusters beyond the city: People, places, and networks. Geoforum, 43(3): 529–539.

HASSINK, R., YANG, C. (2021): Creative industries at the intersection between local agglomeration, national regulation, and global networks. Tijdschrift voor Economische en Sociale Geografie, 112(3): 217–219.

HEMELS, S. GOTO, K. (2017): Tax Incentives for the Creative Industries. Springer Science + Business Media Singapore 2017.

HUGGINS, R., THOMPSON, P. (2014): A Network-based view of regional growth. Journal of Economic Geography, 14(3): 511–545.

HUGGINS, R., THOMPSON, P. (2015): Entrepreneurship, innovation, and regional growth: a network theory. Small Business Economics, 45(1): 103–128.

JACOBS, J. (1969): The Economy of Cities. New York, Vintage.

JACOMY, M., VENTURINI, T., HEYMANN, S., BASTIAN, M. (2014): ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. PLoS One, 9(6): e98679.

JALILI, M., SALEHZADEH-YAZDI, A, ASGARI, Y., ARAB, S. S., YAGHMAIE, M., GHAVAMZADEH, A., ALIMOGHADDAM, K. (2015): CentiServer: A comprehensive resource, web-based application, and R package for centrality analysis. PLoS ONE 10(11): e0143111.

KLOOSTERMAN, R. C. (2010): This is not America: Embedding the cognitive-cultural urban economy. Geografiska Annaler, Series B Human Geography, 92(2): 131–143.

KÖNIG, M. D., BATTISTONM, S., NAPOLETANO, M., SCHWEITZER, F. (2010): Recombinant knowledge and the evolution of innovation networks. Journal of Economic Behavior & Organization, 79(3): 145–164.

LAMPEL, J., GERMAIM, O. (2016): Creative industries as hubs of new organizational and business practices. Journal of Business Research, (69): 2327–2333.

LAZZERETTI, L., CAPONE, C., BOIX-DOMÈNECH, R. (2012): Reasons for Clustering of Creative Industries in Italy and Spain. European Planning Studies, 20(8): 1243–1262.

LI, F. (2020): The digital transformation of business models in the creative industries: A holistic framework and emerging trends. Technovation, 92: 102012.

LORENZEN, M. (2018): The Geography of the Creative Industries: Theoretical Stocktaking and Empirical Illustration. Chapter 16: 305–323. In: Clark, G. L., Feldman, M. P., Gertler, M. S., Wójcik, D. [eds.]: The New Oxford Handbook of Economic Geography, Oxford University Press.

MARSHALL, A. (1890): Principles of Economics. (8th ed). Macmillan and co. Online Library of Liberty, Available at: https://eet.pixel-online.org/files/etranslation/original/Marshall,%20Principles%20of%20Economics.pdf

MCCANN, P. (2008): Globalization and economic geography: the world is curved, not flat. Cambridge Journal of Regions, Economy and Society, 1(3): 351–370.

MORETON, S. (2016): Rethinking 'knowledge exchange': new approaches to collaborative work in the arts and humanities, International Journal of Cultural Policy, 22(1): 100–115.

MORGAN, K. (2004): The exaggerated death of geography: learning, proximity, and territorial innovation systems. Journal of Economic Geography, 4(1): 3–21.

OLDHAM, S., FULCHER, B., PARKES, L., ARNATKEVIČIŪTĖ, A., SUO, C., FORNITO, A. (2019): Consistency and differences between centrality measures across distinct classes networks. PLoS ONE 14(7): e0220061.

POTTS, J., CUNNINGHAM, S. (2008): Four models of the creative industries. International Journal of Cultural Policy 14(3): 233–247

POTTS, J. (2009): Why the Creative Industries Matter to Economic Evolution. Economics of Innovation and New Technology, 18(7): 663–673.

RADOMSKA, J., WOŁCZEK, P., SOŁODUCHO-PELC, L., SILVA, S. (2019): The Impact of Trust on the Approach to Management – A Case Study of Creative Industries. Sustainability, 11(3): 816.

SANTORO, G., BRESCIANI, S., PAPA, A. (2020): Collaborative modes with cultural and creative industries and innovation performance: the moderating role of heterogeneous sources of knowledge and absorptive capacity. Technovation, (92–93): 102040.

SHIACH M., VIRANI, T. (2017): Cultural Policy, Collaboration and Knowledge Exchange. In: Shiach, M., Virani T. [eds.]: Cultural Policy, Innovation and the Creative Economy (pp. 17–30). London, Palgrave Macmillan. Availablle at: https://doi.org/10.1057/978-1-349-95112-3_2

TAO, J., HO, C. Y., LUO, S., SHENG, Y. (2019): Agglomeration economies in creative industries. Regional Science and Urban Economics, 77: 141–154.

VIRANI, T. E. (2015): Do voucher schemes matter in the long run? A brief comparison of Nesta's Creative Credits and Creative works London's Creative Voucher schemes. Creativeworks London Working Paper 10 [online]. Available at: https://core.ac.uk/download/pdf/30697252.pdf

WATSON, A. (2012): Sociological Perspectives on the Economic Geography of Projects: The Case of Project-Based Working in the Creative Industries. Geography Compass, 6(10): 617–631.

WEITZMAN, M. L. (1998): Recombinant growth. Quarterly Journal of Economics, 113(2): 331–360.

YIN, M., DERUDDER, B. (2021): Geographies of cultural industries across the global urban system. Geography Compass, 15(6): e12564.

Please cite this article as:

BALÁŽ, V., JECK, T., BALOG, M. (2022): A geography of creative networks: The case of a small European economy. Moravian Geographical Reports, 30(2): 99–115. doi: https://doi.org/10.2478/mgr-2022-0007

Appendices

Industry code	Weighted degree	Weighted indegree	Weighted outdegree	Closeness centrality	Betweenness centrality	Industry code	Weighted degree	Weighted indegree	Weighted outdegree	Closeness centrality	Betweenness centrality
J62	1,142,651	218,436	924,215	0.7867	0.1443	R90	27,315	27,315	0	0.0000	0.0000
M73	813,369	182,778	630,591	0.7108	0.1190	N77	27,060	22,060	5,000	0.3010	0.0003
G47	660,182	516,179	144,003	0.5842	0.0569	S95	19,845	19,845	0	0.0000	0.0000
M71	452,799	78,765	374,034	0.5842	0.0215	C14	18,220	18,220	0	0.0000	0.0000
G46	387,869	298,167	89,702	0.5315	0.0512	I55	17,100	17,100	0	0.0000	0.0000
M70	342,877	224,154	118,723	0.5463	0.0317	A01	15,740	15,740	0	0.0000	0.0000
N82	291,128	134,195	156,933	0.5960	0.0568	K64	14,370	14,370	0	0.0000	0.0000
J63	183,687	59,235	124,452	0.5619	0.0186	C16	13,641	13,641	0	0.0000	0.0000
M74	171,927	83,569	88,358	0.5315	0.0245	C32	12,093	12,093	0	0.0000	0.0000
F43	148,706	142,861	5,845	0.4184	0.0100	C22	11,883	11,883	0	0.0000	0.0000
L68	122,636	122,636	0	0.0000	0.0000	C20	11,865	11,865	0	0.0000	0.0000
I56	113,657	55,814	57,843	0.4876	0.0087	C33	11,560	11,560	0	0.0000	0.0000
M69	102,574	95,624	6,950	0.3010	0.0014	C28	11,500	11,500	0	0.0000	0.0000
G45	94,025	66,155	27,870	0.4504	0.0006	Q86	10,709	10,709	0	0.0000	0.0000
P85	76,304	41,638	34,666	0.3831	0.0002	M75	9,935	9,935	0	0.0000	0.0000
F41	75,415	41,210	34,205	0.4876	0.0048	C29	9,700	9,700	0	0.0000	0.0000
R93	74,215	54,340	19,875	0.4245	0.0177	D35	9,590	9,590	0	0.0000	0.0000
S96	58,735	39,240	19,495	0.3882	0.0013	C31	9,335	9,335	0	0.0000	0.0000
J59	51,349	22,170	29,179	0.4917	0.0003	C23	8,823	3,833	4,990	0.3782	0.0000
C10	49,762	45,062	4,700	0.4184	0.0083	K66	8,700	3,750	4,950	1.0000	0.0003
H53	48,185	9,090	39,095	0.4836	0.0000	C11	8,700	8,700	0	0.0000	0.0000
N81	43,120	38,285	4,835	0.3512	0.0002	C17	5,000	5,000	0	0.0000	0.0000
J58	39,356	15,978	23,378	0.4646	0.0004	J61	4,580	4,580	0	0.0000	0.0000
C18	37,825	14,220	23,605	0.4126	0.0000	N78	4,325	4,325	0	0.0000	0.0000
H49	33,515	10,290	23,225	0.3782	0.0009	O84	4,315	4,315	0	0.0000	0.0000
C25	32,558	32,558	0	0.0000	0.0000	C26	4,101	4,101	0	0.0000	0.0000
H52	31,249	31,249	0	0.0000	0.0000	C13	4,000	4,000	0	0.0000	0.0000
S94	28,525	23,950	4,575	0.4436	0.0012	C27	3,980	3,980	0	0.0000	0.0000
N79	27,898	14,648	13,250	0.4504	0.0000	E38	3,600	3,600	0	0.0000	0.0000
F42	27,776	23,026	4,750	1.0000	0.0005	H51	1,125	1,125	0	0.0000	0.0000

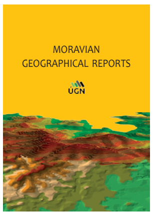
Appendix 1: Industry network statistics (Notes: Values of all degrees are in Euros)
Source: authors' computations

District code	District name	Weighted degree	Weighted indegree	Weighted outdegree	Closeness centrality	Betweenness centrality
BA	Bratislava City	2,049,875	1,002,933	1,046,942	0.6966	0.3581
PO	Prešov	667,678	299,529	368,149	0.4806	0.0339
KE	Košice City	346,985	195,389	151,596	0.4882	0.0579
BB	Banská Bystrica	324,487	146,552	177,935	0.4662	0.0545
ZA	Žilina	183,744	68,676	115,068	0.4769	0.0209
SC	Senec	178,296	24,008	154,288	0.4844	0.0283
PN	Piešťany	177,802	91,153	86,649	0.3543	0.0290
SN	Spišská Nová Ves	177,512	93,165	84,347	0.4493	0.0019
NR	Nitra	159,741	63,003	96,738	0.4460	0.0195
PK	Pezinok	126,633	70,968	55,665	0.4133	0.0078
DT	Detva	100,043	37,333	62,710	0.3388	0.0020
PD	Prievidza	98,159	68,091	30,068	0.3780	0.0197
TV	Trebišov	91,488	4,895	86,593	0.4559	0.0032
ZV	Zvolen	84,667	56,099	28,568	0.4218	0.0061
TN	Trenčín	82,374	46,489	35,885	0.4336	0.0163
SE	Seninca	80,780	29,720	51,060	0.4336	0.0014
KN	Komárno	72,414	33,463	38,951	0.2995	0.0001
LM	Liptovský Mikuláš	72,028	30,349	41,679	0.4627	0.0188
MT	Martin	71,495	25,795	45,700	0.4559	0.0183
TT	Trnava	67,689	41,106	26,583	0.3713	0.0063
HE	Humenné	63,456	39,906	23,550	1.0000	0.0121
GA	Galana	60,789	41,741	19,048	0.4133	0.0045
MI	Michalovce	52,915	22,950	29,965	0.3464	0.0045
BJ	Bardejov	47,593	36,130	11,463	0.3464	0.0112
PB	Považská Bystrica	42,875	33,400	9,475	0.0000	0.0000
VT	Vranov nad Topľou	41,491	8,390	33,101	0.4593	0.0235
SB	Sabinov	41,305	41,305	0	0.0000	0.0000
IL	Ilava	40,960	22,152	18,808	0.4276	0.0007
TO	Topoľčany	38,138	38,138	0	0.0000	0.0000
TS	Tvrdošín	30,471	17,070	13,401	0.3298	0.0034
SA	Šaľa	27,898	19,440	8,458	1.0000	0.0087
NZ	Nové Zámky	26,749	21,749	5,000	0.4133	0.0074
DS	Dunajská Stredaa	24,295	8,375	15,920	0.4189	0.0156
KM	Kysucké Nové Mesto	24,045	15,450	8,595	0.4133	0.0000
KS	Košice-okolie	22,755	12,855	9,900	0.3298	0.0000
SL	Stará Ľubovňa	19,010	0	19,010	0.3500	0.0000
NM	Nové Mesto nad Váhom	18,410	14,110	4,300	0.2627	0.0010
ZM	Zlaté Moravce	16,825	8,675	8,150	0.4218	0.0000
SI	Skalica	16,205	16,205	0	0.0000	0.0000
KK	Kežmarok	15,225	15,225	0	0.0000	0.0000
PU	Púchov	14,120	14,120	0	0.0000	0.0000
BS	Banská Štiavnica	13,623	8,933	4,690	0.4161	0.0000
TR	Turčianske Teplice	13,315	13,315	0	0.0000	0.0000
BN	Bánovce nad Bebravou	13,125	13,125	0	0.0000	0.0000
SV	Snina	12,700	12,700	0	0.0000	0.0000
ML	Medzilaborce	12,450	12,450	0	0.0000	0.0000

Appendix 2: continuation on the next page

District code	District name	Weighted degree	Weighted indegree	Weighted outdegree	Closeness centrality	Betweenness centrality
VK	Veľký Krtíš	11,100	11,100	0	0.0000	0.0000
RV	Rožňavaa	11,052	7,927	3,125	1.0000	0.0087
DK	Dolný Kubín	10,360	10,360	0	0.0000	0.0000
LE	Levoča	9,470	9,470	0	0.0000	0.0000
LV	Levice	9,173	9,173	0	0.0000	0.0000
PP	Poprad	9,095	9,095	0	0.0000	0.0000
RS	Rimavská Sobota	6,600	4,290	2,310	0.3069	0.0002
CA	Čadca	6,114	1,214	4,900	1.0000	0.0013
ZH	Žiar nad Hronom	5,775	5,775	0	0.0000	0.0000
MA	Malacky	5,000	5,000	0	0.0000	0.0000
BR	Brezno	4,963	4,963	0	0.0000	0.0000
SO	Sobrance	4,950	0	4,950	1.0000	0.0000
NO	Námestovo	4,890	4,890	0	0.0000	0.0000
PE	Partizánske	4,528	4,528	0	0.0000	0.0000
RK	Ružomberok	4,450	4,450	0	0.0000	0.0000
LC	Lučenec	3,800	3,800	0	0.0000	0.0000
SP	Stropkov	3,800	3,800	0	0.0000	0.0000
BY	Bytča	3,708	3,708	0	0.0000	0.0000
GL	Gelnica	3,125	3,125	0	0.0000	0.0000

Appendix 2: Regional network statistics (Notes: Bratislava [BA] comprises five urban districts; Košice [KE] comprises four urban districts. Districts are ranked by their weighted degrees. Values of all degrees are in Euros.) Source: authors' computations



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics

journal homepage: http://www.geonika.cz/mgr.html

doi: https://doi.org/10.2478/mgr-2022-0008

Modal split of passenger traffic: The Polish section of EU external borders

Tomasz KOMORNICKI [a], Rafał WIŚNIEWSKI [a *], Karol KOWALCZYK [b]

Abstract

Despite the ongoing processes of territorial integration, especially in Europe, there are still borders that fulfil their original function, namely that of a barrier. In some cases, this function has even been strengthened. Such is the case with Poland's eastern border, which is also the external border of the EU and of the Schengen Area. This article presents the modal split of passenger traffic under conditions of frequent changes in the functions and permeability of borders, against the background of the key drivers behind the volumes of border traffic, i.e. the geopolitical, socio-economic, and infrastructural factors, both in relation to road, rail and border infrastructure. All sections of the border display some marginalisation of railway transport. The Polish eastern border is characterised by a sustained high share of bus transport, which pertains to all sections under analysis. The long waiting times for clearance when travelling in private cars was probably one of the factors behind the creation of the market for collective transport. Private transport is most dominant on the Polish-Russian border, while the largest share of crossings by bus is recorded on the Belarusian border.

Keywords: *borders, cross-border transport, cross-border traffic, modal split, Poland*

Article history: *Received 13 December 2021, Accepted 20 May 2022, Published 30 June 2022*

1. Introduction

The issues of cross-border flows are common and popular research subjects due to the constant changes in conditions and transformations of the function of borders. Several studies have addressed the methodological aspects of border traffic research (e.g. Roider et al., 2018), and the technical and organisational capacity to handle flows (e.g. border crossings under too much strain and options for improving border permeability in technical and organisational terms: Hilmola and Henttu, 2015; Miltiadou et al., 2017; von Arx et al., 2018). Many analyses concern the cross-border mobility of people. Such research is conducted both in regions where territorial cooperation has existed for a long time and the border is an area of intense contacts (e.g. Luxembourg – the Walloon Region; Carpentier, 2012) and in Central and Eastern European countries, where cross-border cooperation has been driven by accession to the European Union (Cavallaro and Dianin, 2019, 2020; Roider et al., 2018). Several other studies address specific types of cross-border mobility (e.g. tourism; Kolosov and Więckowski, 2018).

Moreover, the impact of changes in the functions and permeability of borders on cross-border passenger transport (including its modal split) remains underexplored. In East Central Europe, existing publications in this respect typically describe infrastructure and traffic volume analyses (Komornicki, 1995; Lijewski, 1996; Więckowski, 2003) and relate to historical periods (i.e. before the accession and inflow of funds for infrastructure development, and long before the emergence of increased migration flows in the second decade of the 21st century), or they investigate changes in the public transport network, but from a local or possibly regional perspective (Kołodziejczyk, 2020; Oszter, 2019). There is a lack of studies, however, covering the broader context of changes in border traffic as an element of spatial mobility by modes of transport. In particular, research is needed on the role of transport mode changes with the level of permeability of national borders.

The purposes of this article are: to analyse developments in the volumes of cross-border traffic in the medium-term (1990–2019) by types of border crossing (road, rail, airports); to create an understanding of the factors behind the volumes of cross-border traffic (geopolitical, socio-economic and infrastructural drivers, the latter including transport- and border infrastructure-related determinants); to describe

[a] Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warszawa, Poland (*corresponding author: R. Wiśniewski, e-mail: *rafwis@twarda.pan.pl*)

[b] Institute of Socio-Economic Geography and Spatial Management, Maria Curie Sklodowska University, Lublin, Poland

the transformations in the functions of the Polish eastern border and the level of its permeability (by border section); and subsequently, to examine the impact of dynamic changes in the functions and permeability of the border on modal shifts in cross-border traffic. Thus, we present a description of the sources and methods employed, the characteristics of the Polish eastern border (in terms of the geopolitical, socio-economic, and infrastructural conditions behind the changes in the functions of the border), the dynamics of traffic by the various modes of transport (road, rail and air), and a synthesis showing changes in the modal split of cross-border traffic.

2. Theoretical background

The ongoing process of globalisation is reflected in human mobility, including cross-border flows (Gialis, 2011; Hannonen, 2017; Newman, 2006; Nilsson, 2018; Więckowski et al., 2014; Williams et al., 2001). Such movements can be driven by both economic factors (e.g. labour migration, differences in prices of commodities, differences in exchange rates: Bar-Kołelis and Wendt, 2018; Gerber, 2012; Nerb et al., 2009), transport-related factors (e.g. the growth of low-cost airlines: Vera Rebollo and Ivars Baidal, 2009), and political or geopolitical factors (e.g. integration within the European Union: Komornicki and Wiśniewski, 2017; Ladino, 2017). Cross-border flows also depend on the degree of permeability of a given border, as well as on conditions of the existing infrastructure (including transport and specific infrastructure: Komornicki, 2005). The development of infrastructure mirrors economic development, both of entire countries and border areas, which have their own specificities (Więckowski, 2010). The border can then become an infrastructural barrier, especially when there are additional technical differences (e.g. track gauges). In such a case, the functioning of cross-border transport and of the entire level of transboundary cooperation depends not only on the 'laws' of the market, but also on political situation and will (Haase and Wust, 2004; Wiering and Verwijmeren, 2012), including regional-level decision making (Dołzbłasz, 2018). This has been the case with the Polish eastern border, where the function of the border as a barrier has been preserved and even strengthened (Komornicki et al., 2019).

In recent decades in Europe, especially in Central Europe, two parallel processes have taken place: transformations in border permeability; and modal shifts in passenger transport. To date, these two factors have been described and analysed independently, but it seems vital that the interrelations between the two processes be addressed. The Polish eastern border is a good case study for this type of analysis. Over the last 25 years, the permeability of Poland's eastern border has changed several times (known as the border operation cycle referred to by Więckowski, 2019): from a complete barrier to people and vehicle traffic (before 1989); a period of high permeability in the 1990s; the re-emergence of the border as a barrier to the movement of people (first decade of the 21st century); to the latest phase of a gradual liberalisation of border traffic.

With such dynamic economic developments and changes in the functions of borders, the operation of cross-border connections by public transport has become a huge challenge, which has been mirrored by the modal shifts in border traffic.

Furthermore, cross-border flows, including their underlying structural characteristics, have been well researched for open borders, such as the ones between the internal borders of the Schengen Area (Carpentier, 2012; Mathä and Wintr, 2009; Medeiros, 2019). The lack of formal obstacles (i.e. those imposed at a national level) to movement creates greater opportunities for the growth of border traffic, both when it comes to public transport (i.e. in organisational terms) and travel by private means of transport. Even in border regions with a high degree of territorial integration, however, a number of obstacles to the provision of common public services emerge (Dühr, 2021). The situation is different in the case of formalised boundaries where the legal and administrative conditions come to the fore. Given their nature, such restrictions mean that population flows and public transport develop in a different way, which affects the accessibility of border areas and accessibility to public services (c.f. Rosik et al., 2020). This article fills a research gap with respect to understanding the relationships between the volume of border traffic, border permeability and modal shifts in trans-boundary traffic. Furthermore, the longer period adopted for this analysis allows the role of various types of policies (regional, transport, etc.) on modal change to be evaluated.

3. Data and methods

This study relies on complete data on the border traffic between Poland and Russia (Kaliningrad Oblast), Belarus and Ukraine in the period 1994–2019 (see Tab. 1), i.e. before the COVID-19 pandemic. This extensive database consists of over 5.8 million records. In addition, some more limited characteristics for the years 1990–1993 are used, as well as some values for 1980 as a reference point. The information has been made available by the Polish Border Guard Headquarters. On this basis, changes in the ranks of the individual means of transport in cross-border traffic are examined using descriptive methods, which have provided an in-depth insight into the development of trends and the differences in cross-border processes.

Type of data	Purpose of use
Data of the Border Guard 1990–1993 and 1994–2019 (passenger traffic and traffic by modes of transport)	To identify the volumes and direction of flows, the breakdown of flows into modes and modal shifts
Railway timetables, 1985–2019 (selected editions, printed and digital versions)	To identify organisational changes in rail transport (types and directions of rail connections)
Air carriers, 2019 (scattered sources)	To identify the directions of air connections between Poland and Russia, Belarus and Ukraine in order to supplement the information retrieved from the Border Guard database; data complementary to that of the Border Guard
Permeability of the Polish eastern border in 1990–2019	To assess the relationship between the permeability of individual border sections and changes in border traffic volumes by modes

Tab. 1: Types of data and purpose of use
Source: authors' conceptualisation

The study includes three modes of land transport, namely rail, bus and individual transport, as well as air transport, the data for which come from statistics on the origins of foreigners crossing the border by air. Contrary to the data on volumes available for the land border, this is the only source of information about the direction of air travel. The vast majority of traffic on the Polish sections of the EU border is generated by foreigners, with their greatest share recorded on the border with Ukraine (91.9% in 2019), followed by Belarus (88.3%), and Russia (66.0%)[1]. Citizens of the countries neighbouring Poland dominate on the individual sections of the eastern border, with Ukrainians prevailing on the Polish-Ukrainian border (96.8%, 2019), Belarusians on the Polish-Belarusian border (87.3%; Russians 8.8%), and Russians on the Polish-Russian border (88.0%). Given the above structural distribution of border traffic and the limitations of the air traffic database, the overall assessment of modal shifts in border traffic is based on the arrivals of citizens of Russia, Belarus and Ukraine in Poland. For Russians, the analysis covers two groups – those crossing the border with the Kaliningrad Oblast and those transiting Belarus.

The analysis of traffic by private means of transport and by rail relies on the raw data of the Border Guard, while that for buses, on an estimate of the number of crossings by persons (the database contains only the number of vehicles) based on our own research[2]. The estimate assumes the average bus contains 25 people (only data from the Polish-Lithuanian border, which is part of the Polish eastern border, have been used for this estimate). In order to estimate the number of entries by buses of the three groups of foreigners, use was made – by analogy – of the proportion of a given group of nationals to the total number of entries (foreigners + Poles) at railway border crossings (except for the Polish-Russian border[3]). Meanwhile, the number and share of crossings (entries) made by individual means of transport were determined as the difference between the volumes recorded cumulatively at road crossings and the estimates made for bus transport. Almost all individual (private) crossings were made in passenger vehicles (with up to nine passengers), because there is practically no pedestrian traffic on the Polish eastern border (it is forbidden by law at most crossing points). These data sources also assign drivers of heavy goods vehicles, special vehicles and motorcyclists into the category of individual crossings.

As supplementary material, use was also made of selected railway timetables from 1985 to 2019 (PKP, 1985, 1990, 1991, 1992a,b, 1993, 1995, 2000, 2004, 2009, 2011, 2014, 2018a,b), which include information on international passenger trains. They were useful in identifying the organisational changes in rail transport, including those in the types and destinations of direct cross-border connections. The offer of air carriers was mainly analysed for 2019, due to limited access to archival flight schedules, since they are not retrievable from online flight search engines[4]. Performing a similar analysis for bus connections turned out to be impossible due to the much larger scale of the phenomenon and the lack of integration and archiving of timetables. The research was limited to general information on the number of direct cross-border connections for 2002 (Komornicki, 2003b).

This article also relies on data on the assessment of the degree of permeability of the Polish eastern border in the period 1990–2019, based on a survey conducted among 20 experts in the functions of borders and cross-border mobility. Their assessment comprised the level of permeability, understood as the physical possibility of crossing the state border in passenger cars. The permeability of the borders was assessed by each expert on a scale from 0 to 10, where 0 meant no permeability and 10 no barriers to crossing the border whatsoever. Then, the results were averaged (for each year) to obtain the value of permeability of the individual border sections in successive years.

The Polish eastern border is a typical subsequent boundary (created secondarily to forms of spatial development: Hartshorne, 1936). The Polish-Belarusian and Polish-Ukrainian border crosses an area which belonged entirely to Poland before World War II, while the Polish-Russian border was at that time part of Germany. The length of Poland's land border is 3,071 km, 1,163 km of which form the external EU border analysed in this article. The border consists of three sections: with Russia (Kaliningrad Oblast): 210 km, with Belarus: 418 km, and with Ukraine: 535 km. The Polish-Lithuanian border (104 km) is not included in the study since it constitutes an internal border of the Schengen area. Almost 40% of the Polish segment of the EU external border runs along natural hydrological barriers (mainly along the Bug and San rivers for some 417 km, which form sections of the borders with Ukraine and Belarus), which also contributes to its permeability. In most instances, people cross this border through road checkpoints (96.5%), chiefly by individual (private) means of transport – 81% in 2019. The main underlying motivation is shopping (80.2% of those people crossing) which is undertaken with high frequency (on average several times a month: 41.9%, several times a week: 40.1%) (Statistics Poland, 2020a), which may be the determinant behind the choice of means of transport.

4. Results and discussion

4.1 Polish section of the EU external border: Determinants of border traffic and permeability

The main factors, i.e. geopolitical, socio-economic and infrastructural conditions (road, rail, border infrastructure), behind the volumes of border traffic across the eastern border of Poland can now be discussed. Changes in the permeability of the Polish section of the EU external border are the element that binds these factors together.

---

[1] The shares of the individual sections of the eastern border in border traffic display a similar sequence (2019 data): Ukraine – 66.5%, Belarus – 25.9%, Russia – 7.6%.

[2] The survey was carried out in 2018 on a quarterly basis on the Polish sections of the internal border of the Schengen area and was co-funded by a research grant (see Acknowledgement).

[3] Due to periodic absence of passenger train connections between Poland and the Kaliningrad Oblast in some years, the share of Russians in the number of entries at road border crossings was taken into account when calculating the number of bus passengers.

[4] Scattered sources on past traffic were applied here, including research studies (Komornicki, 2003b; Palmowski, 2015), portals publishing advice for people travelling to Poland (Shoppingpl.com, 2019; Vsetutpl.com, 2019) or reports from industry portals (Avianews.com, 2019; Latamy.pl, 2010; Wirtualnemedia.pl, 2017).

4.1.1 Geopolitical determinants of border traffic

Before the disintegration of the Eastern Bloc, the Polish-Soviet border was distinguished by a very low degree of permeability. It was a kind of 'second Iron Curtain' separating the socialist states of Central Europe from the Soviet Union (Komornicki and Miszczuk, 2010). The rules for crossing the eastern border changed fundamentally in the late 1980s, along with perestroika in the USSR.

After 1989, during the Polish political and economic transformation, the volume of border traffic with Poland's eastern neighbours increased considerably. This not only resulted from the relaxation of the formal procedures, but also from infrastructural developments (opening of new border crossings) and organisational factors (creation of new public transport connections: Komornicki and Wiśniewski, 2017; Komornicki and Kowalczyk, 2018). This was the period of the greatest freedom of movement of people across the eastern border of Poland.

The later changes in volumes of border traffic reflect two overriding factors: global and political (bilateral) ones. The former influence the overall functioning of the economy, including enterprises, while the latter are related to historical conditions (especially Poland's relations with Russia and Ukraine). The latter led to the authorities taking certain decisions, such as introducing embargoes on various types of products, leading to transformations in trade between the countries concerned. At the individual level, the greatest changes in border traffic were triggered by Poland introducing visas for citizens of Russia, Belarus and Ukraine in 2003. This initiated a strong growth of disparities in the situation from one border section to another, which was then modified by Poland's accession into the Schengen area (2007). The greatest variations in the volume and structure of traffic were perceivable on the border with Ukraine, which did not introduce a visa requirement for Polish residents at the time.

Further changes were initiated by the entry into force of local border traffic agreements with Ukraine (2009) and with the Kaliningrad Oblast of the Russian Federation (2012). The Polish-Russian agreement, however, was suspended in 2016 and has not been renewed since then. Meanwhile, the local border traffic agreement with Belarus, signed in 2010, has never entered into force. Instead, eight years later, a unilateral facilitation was put in place whereby EU citizens were allowed to stay on a visa-free basis in Belarusian tourist and recreational zones in Brest and Grodno. The volume of traffic was also influenced by the geopolitical situation in Ukraine (the annexation of Crimea in 2014) and by the lifting of visa requirements for Ukrainian citizens by the Schengen area (2017).

4.1.2 Socio-economic determinants of border traffic

During the post-1989 transformation, Poland plunged into an economic decline with a growing budget deficit, skyrocketing inflation, and the country unable to service its foreign debt (Przybyciński, 2009). Both the economy and society had to face a completely unknown reality and problems related to the functioning of a free market economy. The early years of the transformation were marked by high inflation, which followed the liberalisation of prices and a decline in the level of national income. This was caused by the collapse of internal demand, the loss of 'eastern' outlets (Kołodko, 1992; Skodlarski and Pieczewski, 2011), and the associated decline in industrial production, as well as by the emergence and rapid growth of unemployment, which had been unknown in the times of the Polish People's Republic (PRL)[5]. The following years were characterised by a slow consolidation of growth processes, manifested by a dynamic increase in GDP and sold production of industry.

The consequences of the transformation had a strong impact on volumes of border traffic. Large differences in the prices of goods between Poland and its eastern neighbours incentivised many residents into taking up cross-border trade, not always legal (Komornicki, 2010). An increase in the number of crossings was mainly recorded for the citizens of Russia, Belarus and Ukraine, whose economies were also struggling with the impacts of political and economic transformation.

The 1998 crisis in Russia gave rise to a collapse in flows across the Polish-Russian and Polish-Belarusian border and to some extent also across the Polish-Ukrainian border. Small-scale trade and consequently cross-border traffic at the borders with Belarus and Ukraine saw a short-lived revival in the years 1999–2001, to be interrupted by restrictions in the internal customs policies of both countries and the global situation after September 2001. Further material decline in the volume of border traffic across all three border sections was caused by two factors: the introduction of Schengen visas for citizens of Russia, Belarus and Ukraine, and the global financial crisis (2008). The succeeding years observed a gradual increase in the volume of traffic. This trend did not last long for the Russian and Belarusian borders, however, which can be attributed to a shrinkage in trade with both countries (Russian and Belarusian embargoes on Polish and EU food products, and EU sanctions in connection with the annexation of Crimea), and the suspension of local border traffic with Russia by Poland. On the Polish-Ukrainian border, the upward trend continued and was also observed in 2019 because of a large supply of jobs in the Polish economy. In the period 2010–2018, there was an 18.5-fold increase in the number of work permits issued for Ukrainian citizens (MRPiPS, 2021). It is estimated that at the end of 2019, there were approximately 1.35 million Ukrainians in Poland (Statistics Poland, 2020b).

4.1.3 Infrastructural and organisational determinants of border traffic

Rail transport

The current state of development of the Polish railway infrastructure should be seen in the context of the 19th and the early 20th centuries, when the three powers which ruled Poland because of the late 18th century Partitions, pursued different development policies in the areas they occupied. From the 1840s, the Prussian, and to a much lesser extent, the Austrian authorities, were developing the railway network for economic reasons, while Russians were doing this for strategic and defence reasons, with their efforts limited to the construction of several lines that connected Warsaw with Saint Petersburg, Moscow and some cities within the territory they occupied (Taylor, 2007).

Rail transport has characteristics which make it difficult for carriers in cross-border connections. Contrary to road transport, crossing the border by train requires, *inter alia*,

[5] The Polish People's Republic observed hidden unemployment, which resulted from low productivity and a mismatch between supply and demand. It is estimated that in the 1980s, the actual unemployment rate could have reached 20% (Glikman, 1992).

the rolling stock to be adapted to the infrastructure on both sides of the border (differences in track gauge, power supply systems, signalling or safety standards). The process of approving new rolling stock for service is lengthy and involves the need to obtain formal permits issued by the relevant authorities of both states. As regards passenger transport, a huge challenge is also posed by the preparation of common timetables and the integration of tariffs. As a consequence, the organisation of cross-border rail transport is a more difficult undertaking than operating international bus service, for example.

For many years, until the Central and Eastern European countries embarked on political and economic transformation, it had been more convenient for passengers to cross Poland's borders by train than by car. The growing popularisation of private automobiles resulted in public transport, including the railways, losing their leading roles in handling border traffic. Even in the 1990s, however, border trade played an important role in supporting rail transport. At the time, passenger traffic was reactivated at several crossings on the eastern border previously closed or used only for freight transportation. The first decade of the 21st century saw a nation-wide decline in the network of passenger lines (Komusiński, 2010), which also affected cross-border connections (the reduction concerned the number of local trains which handled cross-border trade, and to a lesser extent long-distance connections). In addition, the technical condition of most of the railway lines which crossed the Polish segment of the EU external border was still unsatisfactory. The growth in investment expenditures on transport infrastructure as a result of the large supply of EU funds only slightly improved the quality of these sections (PLK, 2021).

Road transport

On the eve of the transformation, the development of the Polish road infrastructure corresponded to the transportation structure at that time. In eastern Poland, many local roads were paved to ensure bus transport to remote rural towns. There were hardly any expressways or motorways. Nor were the other main routes adapted to the mass motorisation that had started even before 1989. After 1990, this went hand-in-hand with the rapid decentralisation of the economy and jobs, as well as with difficulties for many public carriers. Additionally, the road infrastructure was deteriorating rapidly since it was being used by increasing flows of heavy goods vehicles, which were gradually taking over freight transport, including bulk shipments. Roads to the eastern border (see Tab. 2), including those which led to existing or planned border crossings, were often in a very poor technical condition.

Generally, the opening of a new crossing merely meant the upgrade of very short sections of road close to the crossing itself, many of which had decayed due to them having been closed to traffic for many years. Deeper in the interior of both Poland and of the neighbouring countries, roads remained unsuitable for transit traffic, especially for trucks. Practically no new routes crossing the border had been built. The situation began to improve, as a result, inter alia, of the inflow of, first-of-all, pre-accession and then, post-accession EU funds. The road accessibility of eastern Poland, and thus also of the border crossings with Russia, Belarus and Ukraine, improved significantly (Komornicki, 2011a). Investments in other parts of Poland, which made it easier for citizens of Eastern Europe to transit Poland to Germany and other European countries, also played a role in the structure of transboundary traffic (Wiśniewski and Komornicki, 2021). For the first time, a modern road infrastructure was brought to Poland's eastern border in 2013 – the A4 motorway, which runs from the German border across Wrocław and Kraków to the border with Ukraine near Lviv (the full-length motorway has been operational since 2016). In the study area it remains the only route in this category. The S22 expressway connects Gdańsk and Elbląg with Kaliningrad Oblast of the Russian Federation (since 2008), but it is a single carriageway. Nevertheless, what was important for cross-border accessibility was the fact that some expressways integrated with the European road system, moved closer to the checkpoints on the eastern border. This was the case with the roads from Warsaw to Lublin (towards Ukraine) and from Warsaw to Białystok (towards Belarus).

The main purpose of the road investments, however, aimed at improving access to the Polish eastern border, was to respond to growing traffic (Komornicki, 2014), and those projects cannot be considered as a driver of modal changes in border traffic. Instead, these changes were driven by an intense growth in the number of motor vehicles, first in Poland, and later also in the neighbouring countries of Eastern Europe (see Fig. 1). The car ownership levels were also triggered by the prestige and social position associated, especially in countries with lower average incomes, with driving your own car, as well as by the potential for a car to communicate the identity of the vehicle owner (Hagman, 2006; Komornicki, 2003a, 2011b; Rosik et al., 2018). In 2010, the share of passenger cars in Poland reached 87.2% of the total transport performance in passenger transport (in the EU 27, only Lithuania had a higher ratio: Rosik et al., 2018). In absolute terms, the most spectacular increase in the number of cars in Poland took place in the 1990s. The car stock was increasing by several hundred thousand vehicles year on year. Moreover,

Border of	Length of the land border (km)	Number of paved roads crossing the border	Number of rail lines crossing the border	Number of border crossings available for regular passenger traffic (and overall number of crossings)				Length of border section per one border crossing available for regular passenger traffic (km)			
				Road		Rail		Road		Rail	
				1991	2019	1991	2019	1991	2019	1991	2019
Russia	210	17	3	1 (2)	4 (4)	1 (2)	0 (3)	210	52.5	105	-
Belarus	418	14	6	2 (3)	5 (7)	2 (5)	2 (5)	209	83.6	209	209
Ukraine	535	11	7	3 (3)	8 (8)	3 (5)	2 (6)	178.3	66.9	178	267.5
TOTAL	**1,163**	**42**	**16**	**6 (8)**	**17 (19)**	**6 (12)**	**4 (14)**	**193.8**	**68.4**	**193.8**	**290.8**

Tab. 2: Transport infrastructure on the Polish eastern border in 1991 and 2019
Source: authors' analysis based on MSW (1991, 2015)

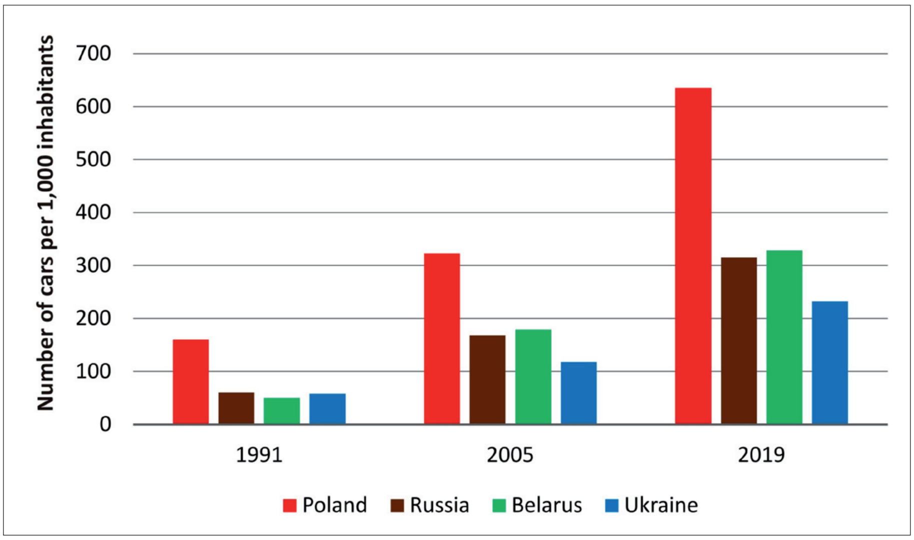


Fig. 1: Motorisation rate in Poland and in selected neighbouring countries
Sources: authors' analysis based on data from: Menes (2018), Auto.24tv.ua (2021), AVTOSTAT (2021), BELSTAT (2021), ROSSTAT (2021), Statistics Poland (2021)

motorisation rates were growing faster during that period in eastern Poland, near the border with the states of the former USSR. This partly resulted from the lower baseline figure (low car saturation in the earlier period), but the fast growth of border trade could have contributed as well (Komornicki, 2011b). A more important role for the modal split, however, was played by the growth of car numbers in the neighbouring countries since, from the start, it was their citizens that constituted the majority of people who crossed the border. In the early 1990s, the motorisation rate in the entire USSR was low and amounted to 59 cars/1,000 inhabitants (in the Russian SSR: 60, in the Ukrainian SSR: 58, in the Belarusian SSR: 50), while in Poland, this was 160 cars/1000 inhabitants (Fig. 1) (Menes, 2018). Along with the transformation of the system and socio-economic development, the rate was growing at the fastest pace in Poland and Belarus.

Border infrastructure

As late as the mid-1980s, there were only three publicly accessible border crossings on the entire eastern border, including that with Lithuania (Kuźnica /railway/, Terespol / rail & road/ – border with Belarusian SSR, and Medyka /rail & road/ – border with the Ukrainian SRR). The remaining railway crossings which existed at the time handled solely freight transport. In addition, there were several road and railway crossings of local importance, available only for exchanging political, social, sport, and other delegations from the border regions of the Polish People's Republic and the USSR (MSW, 1979, 1988).

During the transformation period (especially in the 1990s), the number of border crossings grew rapidly, but at a slower pace on the eastern border than on the western one (cf. Furmankiewicz et al., 2020). After the throughput of the main routes was ensured, subsequent crossings were built at an ever slower pace. The borders are still intersected by a number of paved roads closed to traffic on which no customs and passport clearance is carried out. In 2019, there were 19 publicly accessible road border points on the Polish section of the external border of the EU, 17 of which handled passenger traffic (including one for Polish and Belarusian citizens only) (Fig. 2). Out of the 14 official railway crossings, passenger traffic was handled by eight points, but regular scheduled passenger trains used only four of them (two on the Belarusian section and two on the Ukrainian section). Traffic on the other five crossings, three of which still handle freight traffic, was suspended gradually over the years 1999–2013 (one each on the Polish-Russian and Polish-Belarusian borders, and three on the Polish-Ukrainian border). The activities carried out from 2016 to develop the services available on the Poland-Ukraine routes were the sole exception to the general decline of railway connections (Komornicki and Kowalczyk, 2018). Thus, looking back from the perspective of 2019, changes in the modal split of cross-border traffic were driven by two opposing processes with regard to the infrastructure of the Polish segment of the external EU border. One was the development of border crossing points for road vehicles, and the other was the reduction in the number of railway crossings, which is best evidenced by the indicator of the length of the eastern border section per crossing. Between 1991 and 2019, this value decreased almost threefold for road crossings, and in parallel it increased one and a half times for railway crossings serving regular passenger traffic (see Tab. 1).

Conditions related to transport and regional policies

In addition to the cross-border transport infrastructure, the infrastructure within the neighbouring countries has also changed, especially in Poland where a number of large infrastructure investments supported by the EU's Structural Funds have been completed since 2004. The most noteworthy projects at the national level comprise those built along the TEN-T corridors, including routes leading to the eastern border of the country (inter alia the new A4 motorway to the border with Ukraine, the S20 expressway to the border with the Kaliningrad Oblast, modernisation of the E20 and E30 railway lines from Warsaw to the border with Belarus and from Kraków to the border with Ukraine, respectively). Over time, voivodeship governments have also come to play an important role in delivering transport policy, pursuing Regional Operational Programmes – EU Cohesion Policy investments designed for a lower territorial level. The objectives of transport policies (both at the European and national levels) have gradually shifted towards: a) regional investments to improve accessibility and quality of life; and b) modes of transport that are more climate and environment

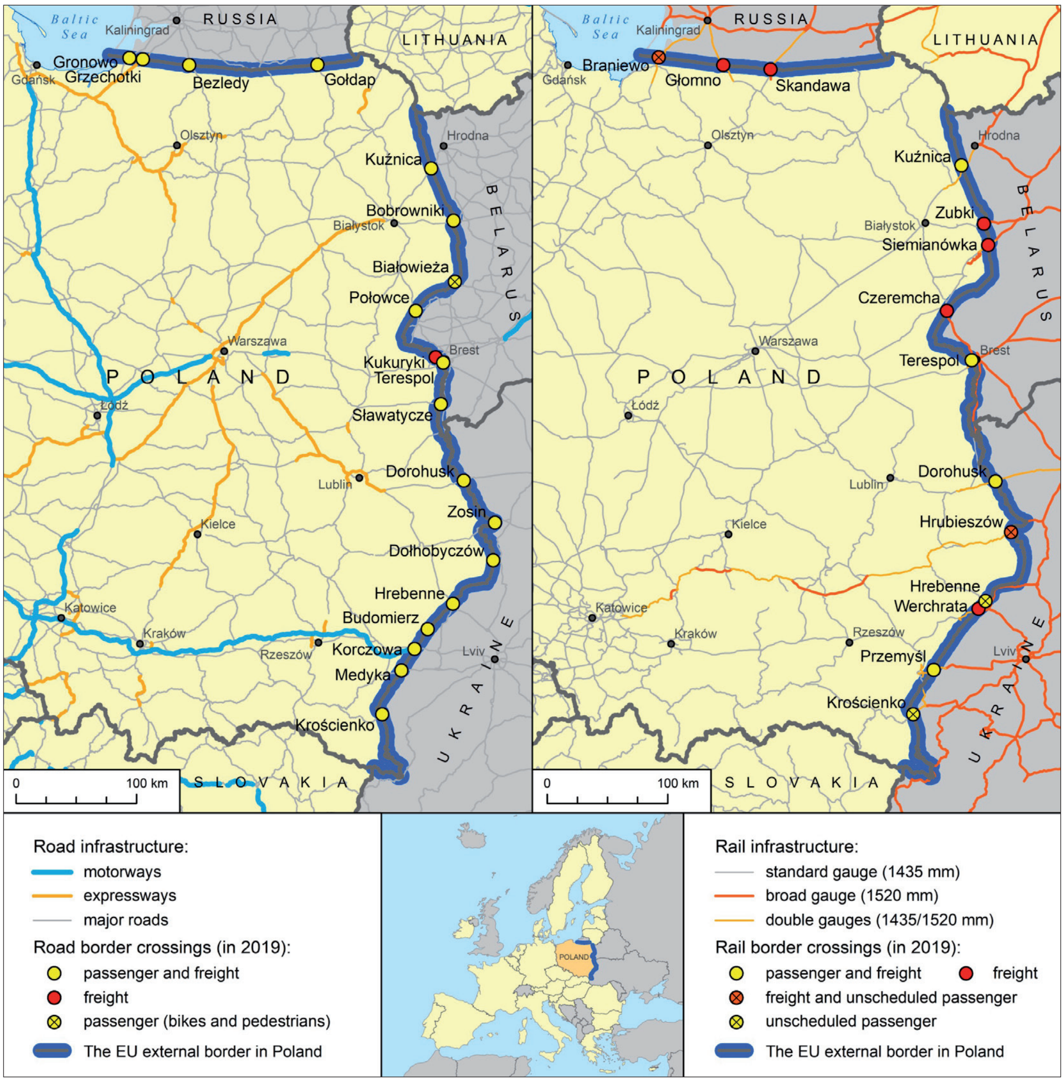


Fig. 2: Transport corridors, border crossings and the Polish section of the EU external border
Sources: authors' analysis based on: MSW (2015), Natural Earth (2021), OpenStreetMap (2021) and PKP (2018a,b)

friendly (Komornicki and Szejgiec-Kolenda, 2020). In border areas, however, this has mainly translated into an improved condition of some regional roads or at best the development of intermodal terminals beside rail routes. Cross-border railways have not benefitted from this policy. After 2015, Poland initiated a program to support public bus transport, which has, however, been oriented to the internal market and has not comprised cross-border connections. Thus, Poland's post-accession transport policy has rather been conducive to the concentration of border passenger traffic in the modal sense (in road transport) and in spatial terms (on the main routes). The scale of investments undertaken in neighbouring countries has been much smaller, with the projects concentrated almost exclusively on the main routes. This has meant, *inter alia*, that, on the Ukrainian side, no new roads have been built to some of the new border crossings (e.g. in Budomierz), with the terminal sections remaining dirt roads.

4.1.4 Permeability

In the period under study (1994–2019), changes in the permeability of the Polish eastern border to passenger traffic varied from one border section to another (see Tab. 3). In the case of the Polish-Belarusian border, these changes were so negligible that they can be considered non-existent, with a relatively low level of permeability of this section of the border (an average of 4.1 on a scale of 0–10). There are noticeable decreases in permeability levels in the years 2004–2009, which were mainly attributable to Poland's accession to the EU and the introduction of a visa regime. Towards the end of the period, there was a noticeable increase in the level of permeability associated with the launch of visa-free travel to so-called 'tourist areas' in Belarus. The entire period saw a relatively low level of permeability of the Polish-Russian border (an average of 4.2), with a marked, but only several-year, increase related to the entry into force of a local border traffic agreement (later suspended by Poland in 2016). The greatest permeability was seen on the Polish-Ukrainian border (5.4 on average). A large increase in the permeability in 2009 stemmed from the introduction of a local border traffic program and then the lifting of visas to the Schengen area (2017).

4.2 Border traffic and modal split

In the period under study, there was a general upward trend in the movement of people across the land sections of the Polish eastern border, currently forming part of the external border of the European Union (Fig. 3). This trend largely resulted from the growing rank of road transport.

Years	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Ukraine	4.4	4.5	4.5	5.4	5.4	5.4	5.4	5.4	5.4	4.5	4.5	4.6	4.6
Belarus	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	3.9	3.9	3.9
Russia	3.9	3.9	4.1	4.2	4.2	4.1	4.1	4.2	4.2	4.0	3.9	3.9	3.9
Years	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Ukraine	4.4	4.4	6.0	6.1	6.1	6.0	6.1	6.1	6.1	6.1	6.4	6.4	6.4
Belarus	3.8	3.8	3.9	4.0	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.6	4.6
Russia	3.7	3.7	3.8	3.8	3.8	5.8	5.8	5.8	5.8	3.9	3.9	4.0	4.0

Tab. 3: Permeability of the Polish section of the external border of the EU
Source: authors' analysis based on a survey

In the 1980s, when the total volume of passenger traffic remained very low, the railway was the leading mode. Socio-economic developments at the beginning of the 1990s enhanced cross-border mobility. Until 1992, there was a fairly steady increase in the number of crossings of the border by both types of transport. The years that followed were characterised by a rise in road transport and a declining rank of railways. Both contradictory tendencies were discontinuous. There were short-term reversals of the trend. The episodic increases of rail traffic, the last of which occurred during the period 2017–2019, were not enough to overcome the marginalisation of this mode.

Road border traffic between the People's Republic of Poland and the Soviet Union was very limited, which was due, inter alia, to formal and organisational constraints. From the beginning of the 1990s, however, its intensity started to grow dynamically on all three sections of the state border (see Fig. 4). For the most part, the fluctuations in overall traffic which were observed at the turn of the century stemmed from the situation at road crossings, and primarily reflected economic activity across the border (favourable conditions for small-scale trade), and, after that, the formal restrictions associated with Poland's accession to the European Union. The first downturn occurred during the Russian financial crisis in 1998 and another occurred after the introduction of visas for citizens of Eastern Europe in 2003. Later increases are associated with a rise in the share of Polish citizens in the traffic, which had ceased to be subject to the visa requirement when travelling to Ukraine. Poles crossed the border, inter alia, to purchase liquid fuels, which artificially increased road traffic statistics. Following the introduction of a limit on the repeated use of reliefs from customs duties, this traffic decreased again. The upward trend in the second decade of the 21st century once again resulted from the travel of citizens of neighbouring countries, mainly Ukrainians, which was stimulated by a local border traffic agreement and the opening of the Polish labour market (Komornicki and Wiśniewski, 2021). This gave rise to shuttle trips by car, often on a weekly basis.

By contrast, coach services play an invariably important role, as far as citizens of neighbouring countries are concerned. They began to take over the transport of small-scale traders from the railways at the beginning of the period under investigation. Later, they also became the means of transport of choice for many foreigners going to work in Poland. The 1990s saw a very rapid growth of international bus connections (Komornicki, 1996). According to 2002 data, 497 return trips to Ukraine, 259 to Belarus, 51 to Russia and 3 to Moldova were operated every week (Komornicki, 2003b). They reached the entire territories of Ukraine and Belarus. In addition to scheduled connections, however, the number of buses recorded on the eastern border (Fig. 5) also includes trips of tourist coaches or coaches rented by groups of small-scale traders. When it comes to bus traffic, the moment Poland joined the Schengen area is reflected by a pronounced decrease in the number of vehicles which crossed the border. From 2009 until the end of the period under study, there was a gradual increase in bus

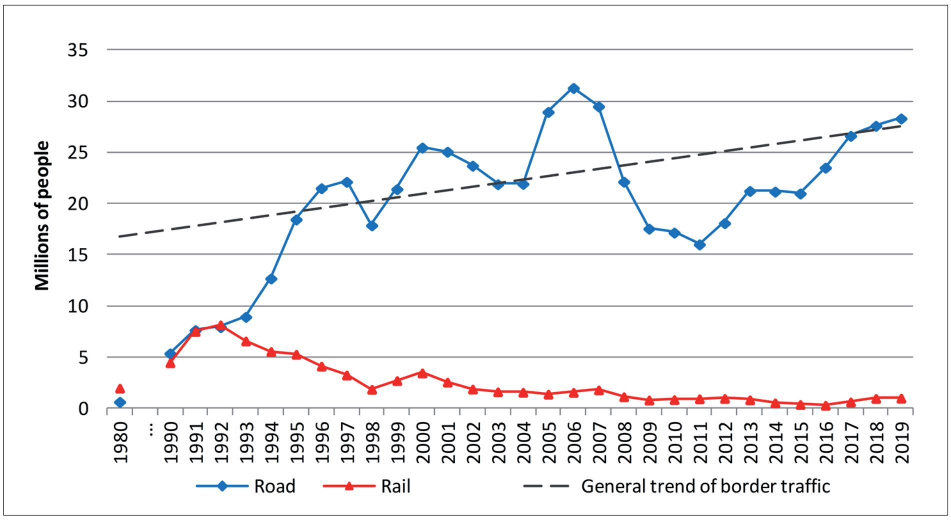


Fig. 3: Passenger traffic at road and rail border crossings on the land segments of the Polish external border of the EU (passport traffic, both directions)
Source: authors' analysis based on data of the Polish Border Guard Headquarters

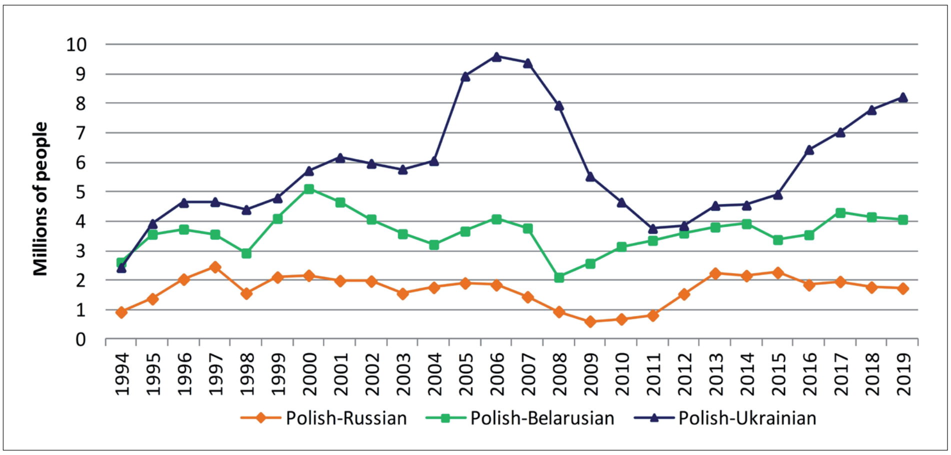


Fig. 4: Passenger traffic at road border crossings on the land segments of the Polish external border of the EU (passport traffic, arrivals to Poland)
Source: authors' analysis based on data of the Polish Border Guard Headquarters

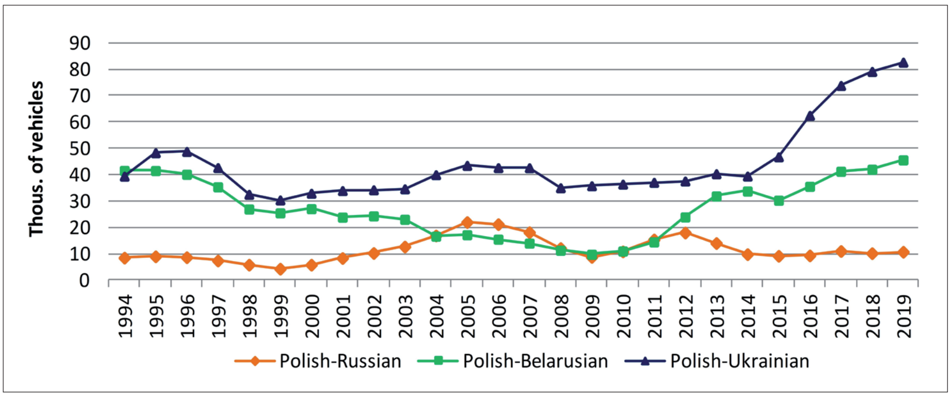


Fig. 5: Number of buses crossing the land segments of the Polish external border of the EU (arrivals to Poland)
Source: authors' analysis based on data of the Polish Border Guard Headquarters

traffic across the Polish-Belarusian and Polish-Ukrainian sections of the border, with a steep increase in 2014 caused by mass labour immigration of Ukrainians into Poland.

In the 1980s, most passenger crossings of the eastern border were made by rail transport (Fig. 6). There were mainly long-distance trains which consisted exclusively of sleeping cars. Their routes linked several Polish cities and six urban centres of the USSR: Moscow, Leningrad (Saint Petersburg), Minsk, Kyiv, Lviv and Vilnius. A separate group was formed by trains which transitted across Poland from many Western European cities towards Moscow. There were also direct connections between Poland and Romania and Bulgaria, which ran across the Ukrainian SSR and served holiday trips (PKP, 1985). Shortly before the collapse of the USSR, the percentage of crossings of the eastern border by rail decreased to approximately 45%. This actually meant a temporary growth in the number of train passengers, as overall land border traffic increased rapidly at the beginning of the 1990s. It was progressively driven by small-scale border trade, fostered by the opening of new local rail connections, first with Belarus and Ukraine, and from 1992 also with Kaliningrad. In contrast, the network of transit connections from Western Europe decreased considerably in favour of air transport (PKP, 1990–1995). In just a dozen or so years, there was a huge decline in the importance of railways in passenger transport, which deepened in the following years. Attempts to activate rail transport by launching long-distance connections (e.g. to Simferopol, Kishinev, Irkutsk, and Astana) were not able to stop the process of marginalisation (PKP, 2000–2014). A slight revival started to be observed from the end of the second decade of the 21st century, mainly as a result of the development of connections with Ukraine (PKP, 2018a,b).

The volume of rail passenger transport expressed in absolute values varied from one segment of the eastern border to another. The Belarusian section (Fig. 7), which served local and long-distance trains (including transit connections) to Moscow and other Russian cities, and initially also to Vilnius (PKP, 1990–2000), ranked first almost over the entire study period. The Ukrainian section ranked second in terms of the values recorded. A similar sequence was observable in the 1980s. For both sections, the volume of passengers peaked at the beginning of the 1990s. In addition, both showed a general downward trend, except that the railways were being marginalised more rapidly on the border with Ukraine. The lowest numbers were seen for traffic between Poland and the Kaliningrad Oblast. Before 1992, passenger transport by rail was nearly non-existent[6] and was not based on public timetables. The opening of a local train route to Braniewo (extended to Gdynia since 1993) and a long-distance connection with Berlin (since 1995) changed little. Shrinking demand for rail

[6] By the time the civilian connections were launched, only soldiers and railway workers could cross the border by rail (Maciążek, 2018). Statistics on border traffic include entries of people belonging to the crews of freight trains.

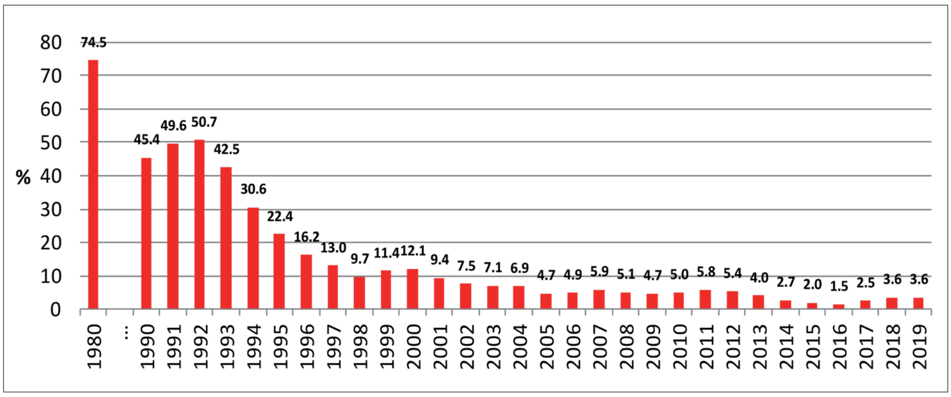


Fig. 6: Role of rail transport in passenger traffic across the land segments of the Polish external border of the EU
Source: authors' analysis based on data of the Polish Border Guard Headquarters

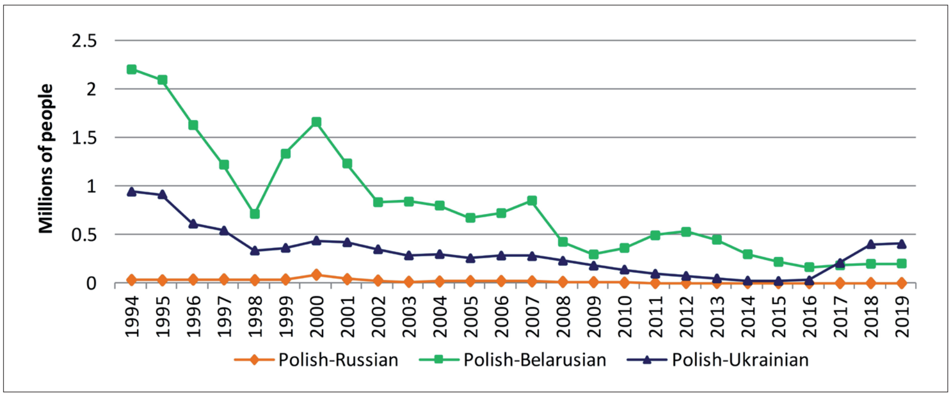


Fig. 7: Passenger traffic at rail border crossings on the land segments of the Polish external border of the EU (passport traffic, arrivals in Poland)
Source: authors' analysis based on data of the Polish Border Guard Headquarters

services resulted in suspension of the local trains at the end of 2012. The irregular connections to the German capital finally ended in 2009 (Anisiewicz, 2007; Maciążek, 2018; PKP, 1992–2011).

Starting from 2017, an increase in flows was recorded on the Ukrainian section of the border, overtaking the volumes observed on the Belarusian border in the next two years. This was brought about, inter alia, by the improvement of the transport offer through the launch of daytime express services from Przemyśl to Lviv and Kyiv and the restoration of a local connection that had not been available since its suspension in the 1990s. The latter activity established links between the Polish city of Chełm and cities of north-western Ukraine (Kovel, Rivne, Zdolbuniv). The above efforts involved bringing in new rolling stock that could travel within Polish territory on broad-gauge sections of track near the border. The absence of the need to replace the bogies and the handling of the customs and passport clearance on board the trains, considerably shortened travel times (PKP, 2014, 2018a,b). These positive signs of the rising rank of railways in cross-border traffic, however, are still incomparable to the rapid growth of car and air transport noticeable in the last decade (cf. von Arx et al., 2018).

The availability of air transport for travel between Poland and the USSR was clearly poorer than that offered by long-distance rail connections. In the 1990s, after the disintegration of the Eastern bloc, international flights were still a luxury good for the average inhabitants of Poland and of the newly created states behind its eastern border. It was somewhat different in the case of Western Europe, where long-distance railway connections to Moscow and Kyiv were largely replaced by air services in the mid-1990s (PKP, 1990–1995). In 2001 there were 19 regular return flights from Poland to Ukraine, 19 to Russia, 8 to Belarus and 2 to Moldova per week (Komornicki, 2003b).

Until the end of the 1990s, of the three groups of foreigners involved, Russians used flight connections to Poland most often. This did not apply, however, to the Warsaw-Kaliningrad route which only appeared in 2002 (Palmowski, 2015). Until 2019, this connection functioned intermittently, showing the smallest flows of people compared to the other three directions (see Fig. 8). Given the relatively short distance, a marginal role of air transport throughout the period is also observable for Belarus, where a slight rebound only occurred in 2013. Flights to Russia (Moscow, Saint Petersburg, Kaliningrad) and to Belarus (Minsk) were and continue to be handled in 2019 only by national carriers (Aeroflot, Belavia, LOT Polish Airlines). These markets continue to be affected by large barriers hindering non-state carriers from entering the market with competitive flights, as a result of which the offer was limited to connections with Warsaw. In 2019, there were 48 such connections per week for Russia, and only 7 for Belarus (Tab. 4).

The dynamic development of low-cost airlines in the first decades of the 21st century revolutionised the market for passenger transport, not only for distant but also for close destinations. Episodically from 2001, and permanently from 2009, Ukrainians had the greatest share in the number of crossings of the eastern air border (Fig. 8). This figure began to climb rapidly in 2016 corresponding to

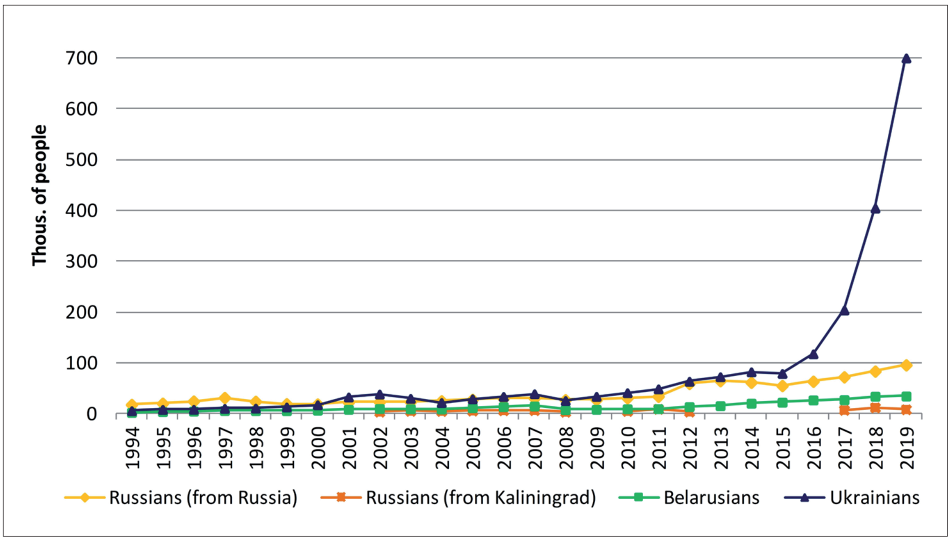


Fig. 8: Arrivals of Russians, Belarusians and Ukrainians at air border crossings in Poland
Source: authors' analysis based on data of the Polish Border Guard Headquarters

demand generated by labour migration to Poland and the subsequent visa waiver. In response to this demand there was a radical extension of the range of destinations on both sides of the border, which was coupled with attractive low-price offers (Shoppingpl.com, 2019; Vsetutpl.com, 2019). Several years before this, the network of connections had still been limited to the capitals of both countries and Krakow, with the flights operated by LOT Polish Airlines and the national airline of Ukraine (Aerosvit, later Ukraine International Airlines).

In 2019 as many as 10 Polish airports offered 189 direct flights to Ukraine per week (Tab. 4). The number of connections served by low-cost carriers (Ryanair, Wizzair) was 83, of which only 11 were operated along the Kyiv-Warsaw route. Out of the 106 connections provided by the national operators, as many as 93 went to Chopin airport in Warsaw. Among Ukrainian cities, four other destinations were available in addition to Kyiv: Lviv, Kharkiv, Odesa and Zaporizhia. The first three of these urban centres were served by both types of carriers, with Lviv in a leading position (45 connections, including 18 low-cost ones).

In the period 1994–2019, the modal split of cross-border traffic evolved differently depending on the section of the border and the group of foreigners – Russians, Belarusians, and Ukrainians. Notwithstanding the general trend characteristic of the entire Polish eastern border, namely the growing share of road transport (and in recent years also of air transport) at the expense of railways, the various modes

		Russia						Belarus
	Airport (IATA code)	Moscow (SVO)	St. Petersburg (LED)		Kaliningrad (KGD)		All airports	Minsk (MSQ)
	Warsaw (WAW)	35/0	7/0		6/0		48/0	14/0
		Ukraine						
	Airport (IATA code)	Kyiv (KBP)	Kyiv (IEV)	Lviv (LWO)	Kharkiv (HRK)	Odesa (ODS)	Zaporizhia (OZH)	All airports
Poland	Warsaw (WAW)	28/0	13/7	21/0	11/0	14/0	6/0	93/7
	Warsaw (WMI)	0/4	–	0/3	–	–	–	0/7
	Kraków (KRK)	7/4	0/4	0/3	0/4	0/2	–	7/17
	Katowice (KTW)	–	0/4	0/3	0/2	0/3	–	0/12
	Wrocław (WRO)	0/3	0/3	0/3	0/2	0/2	–	0/13
	Poznań (POZ)	0/2	0/2	2/0	0/2	0/2	–	2/8
	Gdańsk (GDN)	0/2	0/3	0/4	0/2	0/2	–	0/13
	Bydgoszcz (BZG)	0/2	–	2/0	–	–	–	2/2
	Lublin (LUZ)	–	0/2	–	–	–	–	0/2
	Olsztyn (SZY)	–	–	2/0	–	–	–	2/0
	All airports	35/17	13/25	27/16	11/12	14/11	6/0	106/81

Tab. 4: Direct air connections from Poland to Russia, Belarus and Ukraine with the maximum number of flights per week in 2019 (first value – traditional airlines, second value – low-cost airlines)
Source: Own analysis based on Avianews.com (2019); Latamy.pl (2010); Shoppingpl.com (2019); Vsetutpl.com (2019); Wirtualnemedia.pl (2017); ZOPOT (2020)

of transport on the three sections of border analysed showed different shares over the same time periods. The pace of observed modal shifts was also different (see Fig. 9).

Throughout the period under analysis, road transport, in particular by private means, invariably played the greatest role in the movement of Russians across the Polish-Russian border. The share of buses gradually decreased up to 1999. Subsequently, this trend reversed to exceed, between 2007 and 2011, the level from the first half of the 1990s. This was accompanied by a decline in the overall volume of border traffic, however, caused by the economic crisis and restrictions put in place following Poland's accession to the EU and the Schengen area. Individual transport regained its former position as a result of the operation of local border traffic on this section in 2012–2016. Meanwhile, in the case of Russians who travelled to Poland across Belarus, one characteristic feature, compared to the other sections of the border and groups of foreigners, was the relatively small percentage of crossings by road transport, even towards the end of the study period. Another one was the recurrent prevalence of public transport over private transport (in the periods 1994–1998 and 2007–2019). This resulted, inter alia, from greater distances to travel, thus making travellers opt for the train, bus or plane. The 1990s were a time of a growing share of individual transport, with a fairly stable role of bus transport. Like the border with the Kaliningrad Oblast, private transport began to lose importance after 2004, to become permanently dominated by buses over the ten years that followed. Drivers of passenger cars and trucks would increasingly prefer the Russian-Latvian border of Schengen, giving up transit across Belarus.

More spectacular modal shifts in favour of road transport, and in particular private automobile transport, were observable for the cross-border traffic of Belarusians and Ukrainians. In the initial phase, the development of small-scale border trade and smuggling was one of the driving forces. In both cases, the total share of public transport exceeded 50% only in 1994. Modal changes were proceeding at different rates however. On the Polish-Belarusian border, it was a fairly constant trend, with slight fluctuations and with a stable ratio of private transport to public bus transport, with a clear prevalence of the former. The position of buses only began to improve after 2010. Meanwhile on the Polish-Ukrainian border, the phase of rapid growth in the share of the road sector lasted until 1998. In the following years, the process slowed down, but continued until 2015, when new air and railway services started to be offered.

At the same time, unlike the Polish-Belarusian border, this section experienced a more marked decline in the share of bus transport (despite an upward trend recorded in absolute values), with a simultaneous growing predominance of private transport. The clearance waiting times, as analysed in the context of the purpose of the travel, was one factor that may have had an impact on the internal breakdown of road traffic. In the case of small-scale trade (1990s) or shopping (last decade), a decisive role was played by the possibility of transporting larger amounts of goods, which meant that private cars and vans were opted for, regardless of the travel time. With the growing share of commuting to work in Poland in overall travel, crossing the border rapidly came to the fore. This was catered for by scheduled buses, which bypassed queues at the border crossings.

From the very beginning, rail transport, at the expense of which the modal shift in question took place, was of marginal importance in the movement of people across the Polish-Russian border. It was only in 1994 and 2000 that a more noticeable percentage of Russians who travelled from the Kaliningrad Oblast, chose this method of crossing the border. Aside from a slight rebound between 2007 and 2009, rail transport on this section underwent further

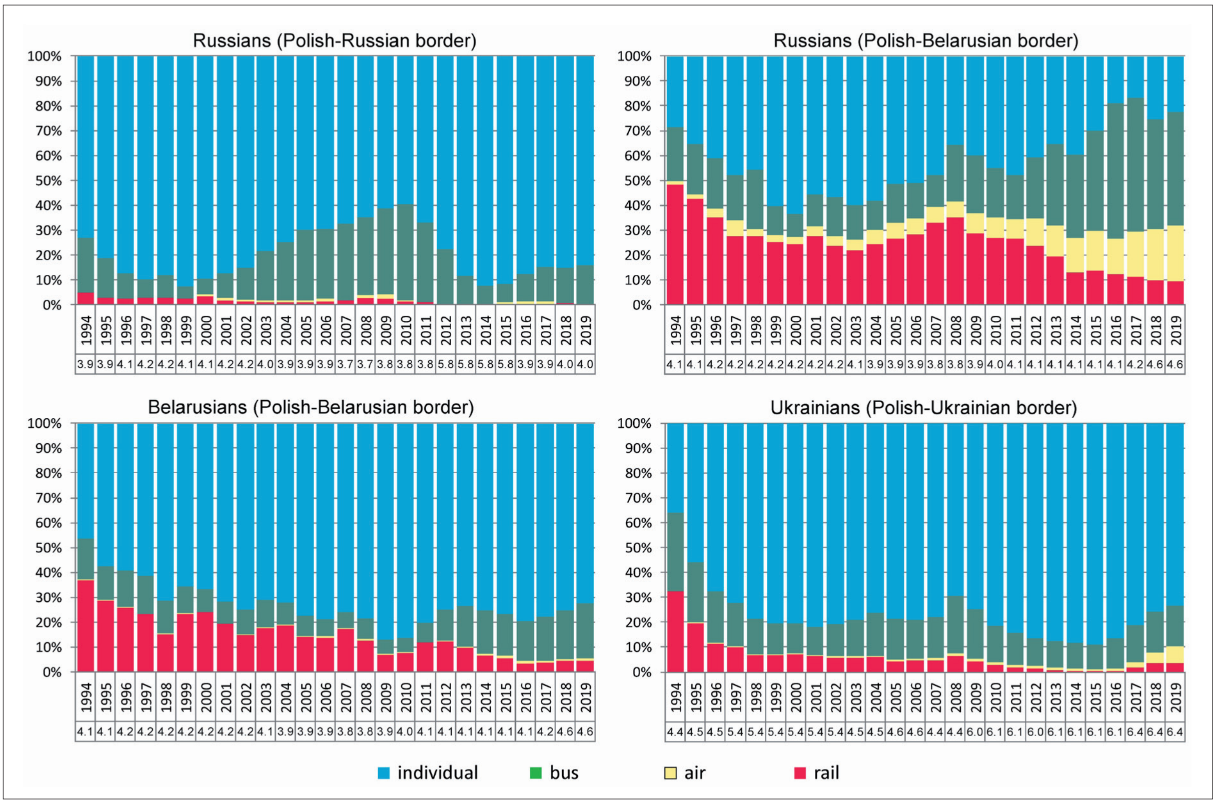


Fig. 9: Modal split changes and border permeability rate 1994–2019
Source: authors' analysis based on data of the Polish Border Guard Headquarters and our research

marginalisation, which led to the suspension of timetable-based transport in the second decade of the 21^{st} century. Later attempts to restore them ended in 'fiasco', which was due to the lack of political will to re-establish local border traffic. Meanwhile, the railway was an important means of transport for Russians who used long-distance connections across Belarus. In the first half of the 1990s, rail's share in the modal structure here reached almost 50%. Despite the subsequent regression (excluding a five-year growth phase in 2004–2008), the percentage of crossings of the Polish-Belarusian border on trains by citizens of the Russian Federation was still much higher than in the case of the other two groups of nationals. Until as late as 2012, it was also higher than the number of entries by bus. Belarusians who travelled to Poland by public transport would also choose trains over buses for many years, but the share of railways in the modal split of cross-border traffic became lower than in the case of Russians on the same section as early as 1994, and was to decrease gradually in the years that followed. This stemmed, inter alia, from the gradual reduction in the number of local cross-border connections being offered.

The Polish-Ukrainian border is the most illustrative example of the marginalisation of rail transport. Buses very rapidly began to play a leading role in the arrivals of Ukrainians by public transport. The proportions of the shares of the two modes were similar only in 1994, with a slight advantage to the railways. The 1990s were characterised by an even faster loss of volumes to individual transport. After 2000, the share of railways saw a further decline to be marginalised totally in 2014–2016, when no local connections were in operation anymore, and the long-distance service was reduced to a minimum. It was only in 2017 that the long-term downward trend started to reverse as a result of the launch of a new, more convenient network of connections at the end of 2016. In 2018, this share continued to grow, but a year later it stalled at approximately 3.5%.

The reasons for the long-term decline of rail transport in cross-border passenger traffic are complex. They include the incompatibility of the infrastructure, its deterioration and the competitiveness of other modes of transport, the organisation of railway services, with the indirect impact of formal and customs-related restrictions. The above problems pertain not only to the eastern border, which is peculiar, but also to the other sections of the Polish border (cf. Gamon and Naranjo Gomez, 2019).

The condition of railway infrastructure in eastern Poland, including that used for cross-border traffic, had been deteriorating uninterruptedly until Poland's accession to the European Union. Reverse trends were observable only as a result of the influx of EU funds and the modernisation of some routes, mainly trunk lines. The low competitiveness of rail transport to Eastern Europe (compared to bus carriers, and later also low-cost airlines) resulted from long waiting times at border checkpoints (due to different track gauges, among other reasons), rather than from the low speed of travel. The nature of the operations of railway undertakings, notably their lower flexibility and fewer possibilities for matching the train routes to demand than in the case of bus and air transport, was another factor (Perennes, 2017). An indirect role was also played by the transport policies of the neighbouring countries. Individual countries first strive to ensure an appropriate network of domestic connections, and then of international ones (cf. von Arx et al., 2018). This study demonstrates that cross-border rail transport proved to be highly inflexible in the face of systemic changes (economic transformation), geopolitical developments (visa and customs regimes), and sectoral transitions (competition from other modes of transport; Komornicki and Kowalczyk, 2018). There are also good examples of the functioning of cross-border transport, but they mainly comprise seasonal tourist connections (e.g. between Maribor-Prevalje, Slovenia and Bleiburg-Pliberk, Austria; Interreg Central Europe, 2022, or the connection that has been announced between Kraków, Poland and Split, Croatia to be operated by the Czech carrier RegioJet; TVN24.pl, 2022).

The position of railways in the segment of international long-distance transport was also weakened by the extension of the air offer, especially in the second decade of the 21^{st} century. This did not concern the Kaliningrad Oblast and Belarus, however, whose proximity and isolated markets resulted in the share of air traffic in these directions to be minimal over the entire period considered. It appears to be completely different for Russian travellers flying through the airspace of Belarus (mainly from Moscow and St. Petersburg) and Ukrainians, who preferred air travel on account of the distance. In the case of Russians, the role of air transport in cross-border traffic with Poland became noticeable as early as the 1990s, but the greatest upward trend in this regard was seen after 2011. In the middle of the second decade of the 21^{st} century, the air sector began to compete with railways in real terms. In 2019, more than twice as many Russians came to Poland by air as by train. Despite the larger and growing number of arrivals by Ukrainians in absolute terms, the share of air traffic in the modal split became pronounced much later, with a much lower share than that recorded among Russians. This was due to the fast pace of development of Polish – Ukrainian road transport. The years 2013–2015 even saw a decrease in the share of air traffic, which had already overtaken rail transport by that time. The share of rail equalled that of air transport in 2017. In the last two years, however, the aviation sector strengthened its position. In 2019, almost twice as many Ukrainians arrived in Poland by air as by rail. The transformations described above are an interesting example of competition between two niche modes of transport, despite the prevalence of the road sector.

On the Belarusian section (cross-border traffic of Belarusians and Russians), the permeability of the border did not have any impact on modal change (see Fig. 9). In the absence of major changes in the level of permeability, the share of individual means of transport in the number of crossings of this border changed significantly, which was the result of general trends (increasing share of crossings made by cars) or the specificity of the Belarusian section (a high share of trains in the crossings made by Russians in long-distance travel). On the Polish-Russian border, there is a strong predominance of crossings made by passenger cars following the improvement of permeability by the signature of the local border traffic agreement. The Ukrainian section also displays a discernible growth in car traffic at times of greater permeability, *inter alia* because of the introduction of local border traffic. The higher permeability of this border coincided with a relatively large share of air crossings. This probably stems from the market's response to the demand produced by labour migration to Poland. It should not be forgotten, however, that this is concurrent with the easing of the visa regime and the associated limitation of the function of the border as a barrier, especially a formal one. Thus, the problem of permeability concerns formal issues to a greater extent than the technical possibilities of crossing the border (border checkpoints).

It follows from the outcomes of this study that increased permeability typically led to an intensification of border traffic. In parallel, longer journeys (e.g. between the large cities of Poland and of neighbouring countries, but also generally trips to work in Poland) took place during periods of greater formal restrictions too. As there is no strictly local public transport across the eastern border, changes in permeability had an indirect effect on the modal split of traffic. Better permeability is also one of the stimulants of air transport, especially by low-cost carriers. Against such a background, the role of railways is more difficult to interpret. On the one hand, for many years, cross-border travel by train would decline both at times of decreased and increased permeability, but it was mainly a secondary consequence of changes in the overall intensity of car traffic. On the other hand, in the final years of the study period, the improvement in the level of permeability on the Ukrainian border was coupled with a slow revival of rail transport. It can be anticipated that achieving a certain degree of permeability of the formal border is a condition for the formation of a modal split similar to that of internal journeys. Then, the border ceases to be a factor that shapes the breakdown of traffic. Further modal changes in passenger transport are conditioned by other factors.

6. Conclusions

The aim of this study was to identify the impact of changes in the function of the eastern border of Poland (which is also part of the EU external border) and in the level of its permeability on modal shifts in cross-border traffic over the years 1994–2019. In order to achieve this, use was made of data from the Border Guard Headquarters and our own research activities to allow the volumes of border traffic for certain categories to be estimated. Three types of land transport were analysed: rail, air and road (by bus and in private cars).

All sections of the border display the marginalisation of railway transport. A relatively high contribution of railways is still being recorded on the Belarusian border on account of long-distance travel (between Moscow and European cities). Ignoring the intermodal shifts between types of public transport, the key role was played by the growing predominance of private car transport in Russia, Belarus and Ukraine. Despite this, the Polish eastern border is characterised by a sustained high share of bus transport which pertains to all the sections under analysis. Private transport is most dominant on the Polish-Russian border, while the largest share of crossings by bus is recorded on the Belarusian border (both among Russians and Belarusians). Air transport is most favoured when it comes to Russians on the Belarusian section and in the case of Ukrainians. One inherent feature of road traffic, especially of travel by car, is congestion, which occurs on sections with a lower degree of permeability due either to the degree of border formalisation or insufficiently developed transport infrastructure (see Komornicki, 2008). The long waiting times for clearance when travelling in private cars was probably one of the factors behind the creation of the market for collective transport.

This analysis made it possible to distinguish several periods of modal shifts in passenger traffic on the Polish section of the EU external border:

- the 1990s, when rapid modal shifts were driven by the liberalisation of the economy (previously, the position of the railways had been maintained artificially by regulations of the centrally planned economy), booming cross-border trade, competition from bus transport, and mass motorisation in Poland and then also in the neighbouring countries; during this period, similar modal changes took place across all the sections of the border;
- the 2000–2011 period, when the changes were due to the low competitiveness of the railways (deterioration of the network) and the closure of unprofitable connections (including cross-border ones), but also by Poland's accession to the EU and the Schengen area, as well as by customs-related conditions; during the period, the pace of modal change on the various borders began to vary;
- the 2012–2016 period in which further changes were triggered by the inadequate offer of services from railway operators and them losing out in the competitive struggle, not so much with private car transport, which had happened earlier, but rather with public bus and air transport; and
- the 2017–2019 period, when the permeability of the Polish-Ukrainian border clearly improved (inter alia because of the lifting of Schengen visas for Ukrainian citizens), and when the modal split began to be determined more by market conditions, with a growing share of air transport and the first signs of the revival of the railways; at the same time, the situation along the Belarusian and Russian sections of the border did not radically change up to 2019.

While the first two periods mentioned above mirror objective economic and political processes (the decline in cross-border rail traffic and mass motorisation were largely unavoidable), the post-2012 period was strongly influenced by an actual transport policy, especially when it comes to Polish-Ukrainian relations. The huge increase in traffic between the two countries, associated mainly with migration (and not only with cross-border trade), opened a window of opportunity for enhancing the role of both rail and air transport. This created new opportunities for observing cross-border processes in transport terms, especially in the context of ever closer Polish-Ukrainian cooperation. The aspect of the efficiency of public transport and the mechanisms of adjusting the demand and supply of transport services in response to the huge influx of economic migrants from Ukraine and, to a lesser extent, from Belarus, seems to be of particular interest. Further research into modal shifts in border traffic seems advisable. Such research, however, must go hand-in-hand with studies into the territorial system of the social ties that generate the traffic (labour migrations, students' travel, tourism, family visits, transit). This would provide an insight into the modal structure of cross-border traffic in terms of the underlying motivations.

This analysis is also useful in formulating guidance for the broad transport policies and border regimes. Research shows that the investment activities carried out to date have indirectly stimulated modal changes towards a greater share of car transport. The construction of the new TEN-T network of road routes (on the Polish side of the border) has increased the share of cross-border road transport, especially in private automobiles. The reactivation of regional cross-border railway lines (along the sections that do not require gauge change) could help to slow down this trend locally. A role is also played by the regulations that limit pedestrian traffic on most crossings, which promote the use of private cars even for very short journeys. Ultimately, however, increasing the share of rail traffic requires that East

European countries be integrated into the network of high-speed intercity connections in order to be competitive with both private car and air transport. In the case of the rail connections across the Polish eastern border, this applies in the first place to the Polish-Ukrainian connections along the Krakow-Lviv, Warsaw-Lviv, Warsaw-Kovel-Kyiv routes. The feasibility of such actions in the case of Belarus and Russia depends on future geopolitical developments.

Acknowledgement

This research was funded by the National Science Centre (Poland) grant: Economic, social and geopolitical conditioning of the border traffic – foundations for modelling and forecasting on the example of Poland (BORDER-TRAF), UMO-2016/21/B/HS4/03019.

References:

ANISIEWICZ, R. (2007): Transport kolejowy w Obwodzie Kaliningradzkim jako czynnik rozwoju współpracy transgranicznej. In: Kiniorska, I., Sala, S. [eds.]: Nauki geograficzne w badaniach regionalnych: Rola geografii społeczno-ekonomicznej w badaniach regionalnych (pp. 401–407). Kielce, Instytut Geografii Akademii Świętokrzyskiej.

AUTO.24TV.UA (2021): Tri fakta ob avtoparke Ukrainy v 2019 godu: infografika. Auto 24 website [cit. 24.08.2021}. Available at: https://auto.24tv.ua/ru/tri_fakta_ob_avtoparke_ukrainy_v_2019_godu_infografika_n19433

AVIANEWS.COM (2019): Ryanair otkryl prodazhi biletov na shestoy marshrut iz Odessy [online]. Avianews.com website [cit. 04.08.2021]. Available at: https://www.avianews.com/ukraine/2019/04/17/ryanair_odessa_gdansk_tickets

AVTOSTAT (2021): Skol'ko avtomobiley prikhodilos' na 1000 zhiteley v SSSR? AVTOSTAT website [cit. 24.08.2021]. Available at: https://www.autostat.ru/infographics/46910/?nw=1610426452000

BAR-KOŁELIS, D., WENDT, J. A. (2018): Comparison of cross-border shopping tourism activities at the Polish and Romanian external borders of European Union. Geographia Polonica, 91(1): 113–125.

BELSTAT (2021): Transport. Godovyye dannyye. BELSTAT website [cit. 24.08.2021]. Available at: https://www.belstat.gov.by/ofitsialnaya-statistika/realny-sector-ekonomiki/transport/godovye-dannye/

BOGGS, S. W. (1940): International Boundaries: A Study of Boundary Functions and Problems. New York, Columbia University Press.

BORDER-TRAF (2021): Economic, social and geopolitical determinants of border traffic – bases for modelling and forecasting on the example of Poland. Unpublished data of the research project, Warszawa, IGiPZ PAN.

CARPENTIER, S. (2012): Cross-border local mobility between Luxembourg and the Walloon region: an overview. European Journal of Transport and Infrastructure Research, 12(2): 198–210.

CAVALLARO, F., DIANIN, A. (2019): Cross-border commuting in Central Europe: features, trends and policies. Transport Policy, 78: 86–104.

CAVALLARO, F., DIANIN, A. (2020): Efficiency of public transport for cross-border commuting: An accessibility-based analysis in Central Europe. Journal of Transport Geography, 89: 102876.

DOŁZBŁASZ, S. (2018): A network approach to transborder cooperation studies as exemplified by Poland's eastern border. Geographia Polonica, 91(1): 63–76.

DÜHR, S. (2021): German stakeholder perspectives on the provision of cross-border public services. EUROPA XXI, 40: 27–46.

FURMANKIEWICZ, M., BURYŁO, K., DOŁZBŁASZ, S. (2020): From service areas to empty transport corridors? The impact of border openings on service and retail facilities at Polish-Czech border crossings. Moravian Geographical Reports, 28(2): 136–151.

GAMON, W., NARANJO GÓMEZ, J. M. (2019): Main problems of railway cross-border transport between Poland, Germany and Czech Republic. Sustainability, 11(18): 4900.

GERBER, P. (2012): Advancement in conceptualizing cross-border daily mobility: The Benelux context in the European Union. European Journal of Transport and Infrastructure Research, 12(3): 178–197.

GIALIS, S. E. (2011): Trans-border mobility and integration in border regions: Albanian migrants in Epirus and the Ionian Islands in Greece. Journal of Balkan and Near Eastern Studies, 13(3): 303–322.

GLIKMAN, P. (1992): Ukryte bezrobocie. Życie Gospodarcze, 13: 8.

HAASE, A., WUST, A. (2004): Advancing integration or constructing new barriers to co-operation? Stimuli and restrictions for cross-border communication at the Polish eastern border on the eve of EU enlargement. Journal of Borderlands Studies, 19(2): 77–100.

HAGMAN, O. (2006): Morning queues and parking problems. On the broken promises of the Automobile. Mobilities, 1(1): 63–74.

HANNONEN, O. (2017): Bordering the "other": The case of the Finnish-Russian border. Fennia, 195(1): 113–117.

HARTSHORNE, R. (1936): Suggestions on the terminology of political boundaries. Annals of the Association of American Geographers, 26(1): 56–57.

HILMOLA, O. P., HENTTU, V. (2015): Border-crossing constraints, railways and transit transports in Estonia. Research in Transportation Business & Management, 14: 72–79.

INTERREG CENTRAL EUROPE (2022). Cross-border summer train between Slovenia and Austria [online]. Interreg Central Europe website [cit. 17.02.2022]. Available at: https://www.interreg-central.eu/Content.Node/Cross-border-summer-train-between-Slovenia-and-Austria.html

KOLOSOV, V., WIĘCKOWSKI, M. (2018): Border changes in Central and Eastern Europe: An introduction. Geographia Polonica, 91(1): 5–16.

KOŁODKO, G. (1992): Transformacja polskiej gospodarki: sukces czy porażka?. Warszawa, Polska Oficyna Wydawnicza „BGW".

KOŁODZIEJCZYK, K. (2020): Cross-border public transport between Poland and Czechia and the development of the tourism functions of the region. Geographia Polonica, 93(2): 261–285.

KOMORNICKI, T. (1995): Transgraniczna infrastruktura transportowa Polski. Przegląd Geograficzny, 67(1–2): 45–53.

KOMORNICKI, T. (1996): Bus connections between Poland and other European countries. Transport Reviews, 16(2): 99–108.

KOMORNICKI, T. (1999): Granice Polski: Analiza zmian przenikalności w latach 1990–1996. Geopolitical Studies, 5. Warszawa, IGiPZ PAN.

KOMORNICKI, T. (2003a): Factors of development of car ownership in Poland. Transport Reviews, 23(4): 413–431.

KOMORNICKI, T. (2003b): Przestrzenne zróżnicowanie międzynarodowych powiązań społeczno-gospodarczych w Polsce. Prace Geograficzne, 190. Warszawa, IGiPZ PAN.

KOMORNICKI, T. (2005): Transport transgraniczny jako pojęcie geograficzne. Prace Komisji Geografii Komunikacji PTG, 11: 55–63.

KOMORNICKI, T. (2008): Transborder transport. The case of Poland's present and future Schengen area boundaries. In: Leibenath, M. et al. [eds.]: Cross-border Governance and Sustainable Spatial Development: Mind the Gaps! (pp. 133–146). Berlin-Heidelberg, Springer.

KOMORNICKI, T. (2010): Flows of persons and goods across the Polish segment of the outer boundary of the European Union – results of a research project. Europa XXI, 20: 9–29.

KOMORNICKI, T. (2011a): Dostępność drogowa polskich granic. Prace Komisji Geografii Komunikacji PTG, 18: 83–96.

KOMORNICKI, T. (2011b): Przemiany mobilności codziennej Polaków na tle rozwoju motoryzacji. Prace Geograficzne, 227. Warszawa, IGiPZ PAN.

KOMORNICKI, T. (2014): Spatial and social effects of infrastructural integration in the case of the Polish borders. In: Dienel, H. L., Schiefelbusch, M. [eds.]: Linking networks: The formation of common standards and visions for infrastructure development (pp. 187–208). London, Routledge.

KOMORNICKI, T., KOWALCZYK, K. (2018): Role of rail in passenger border traffic between Poland and Ukraine – a dynamic approach. Barometr Regionalny, 16(2): 133–148.

KOMORNICKI, T., MISZCZUK, A. (2010): Eastern Poland as the borderland of the European Union, Quaestiones Geographicae, 29(2): 55–69.

KOMORNICKI, T., SZEJGIEC-KOLENDA, B. (2020): The development of transport infrastructure in Poland and the role of spatial planning and cohesion policy in investment processes. Planning Practice & Research, 1–20.

KOMORNICKI, T., WIŚNIEWSKI, R. (2017): Border traffic as a measure of trans-border relations. Mitteilungen der Österreichischen Geographischen Gesellschaft, 159: 151–172.

KOMORNICKI, T., WIŚNIEWSKI, R. (2021): The Role of Poland's Eastern Border in Global Migration Systems. EUROPA XXI, 40: 83–98.

KOMORNICKI, T., WIŚNIEWSKI, R., MISZCZUK, A. (2019): Delimitacja przygranicznych obszarów problemowych. Przegląd Geograficzny, 91(4): 467–486.

KOMUSIŃSKI, S. (2010): Przekształcenia przestrzenne sieci pasażerskiego transportu kolejowego w Polsce w latach 1988–2008. Prace Komisji Geografii Komunikacji PTG, 17: 1–140.

LADINO, M. T. (2017): Borders, mobility and the transborder space: Reflections for a discussion. Estudios Fronterizos, 18(37): 61–80.

LATAMY.PL (2010): LOT wraca na trasę Warszawa – Kaliningrad [online]. Latamy.pl website [cit. 22.05.2021]. Available at: https://www.latamy.pl/4pp,1013,lot_wraca_na_trase_warszawa__kaliningrad.html

LAURILA, J. (2003): Transit transport between the European Union and Russia in light of Russian geopolitics and economics. Emerging Markets Finance and Trade, 39: 27–57.

LIJEWSKI, T. (1996): Graniczne linie kolejowe w przeszłości i perspektywie. Prace Komisji Geografii Komunikacji PTG, 1: 9–19.

MACIĄŻEK, F. (2018): Połączenia kolejowe pomiędzy Polską i Obwodem Królewieckim. TTS Technika Transportu Szynowego, 25(1–2): 28–40.

MAKKONEN, T., WILLIAMS, A. M., WEIDENFELD, A., KAISTO, V. (2018): Cross-border knowledge transfer and innovation in the European neighbourhood: Tourism cooperation at the Finnish-Russian border. Tourism Management, 68: 140–151.

MATHÄ, T., WINTR, L. (2009): Commuting flows across bordering regions: a note. Applied Economics Letters, 16(7): 735–738.

MEDEIROS, E. (2019): Cross-border transports and cross-border mobility in EU border regions. Case Studies on Transport Policy, 7: 1–12.

MENES, M. (2018): Rozwój motoryzacji indywidualnej w Polsce w latach 1990–2015. Przegląd Komunikacyjny, 73(4): 14–25.

MILTIADOU, M., BOUHOURAS, E., SOCRATES, B., MINTSIS, G., TAXILTARIS, C. (2017): Analysis of border crossings in South East Europe and measures for their improvement. Transportation Research Procedia, 25: 603–615.

MINGHI, J. V. (1963): Boundary studies in political geography. Annals of the Association of American Geographers, 53(3): 407–428.

MRPiPS (2021): Zezwolenia na pracę cudzoziemców. Warszawa, Departament Rynku Pracy, Ministerstwo Rodziny Pracy i Polityki Społecznej [online]. [cit. 24.08.2021]. Available at: https://psz.praca.gov.pl/-/8180075-zezwolenia-na-prace-cudzoziemcow

MSW (1979): Zarządzenie Ministra Spraw Wewnętrznych z dnia 20 lutego 1979 r. zmieniające zarządzenie w sprawie przejść granicznych przeznaczonych dla ruchu granicznego. Monitor Polski, 1979(7): 52.

MSW (1988): Zarządzenie Ministra Spraw Wewnętrznych z dnia 29 czerwca 1988 r. zmieniające zarządzenie w sprawie przejść granicznych przeznaczonych dla ruchu granicznego. Monitor Polski, 1988(19): 167.

MSW (1991): Zarządzenie Ministra Spraw Wewnętrznych z dnia 11.06.1991 r. w sprawie ogłoszenia przejść granicznych, rodzaju ruchu dozwolonego przez te przejścia oraz czasu ich otwarcia. Monitor Polski, 1991(20): 143.

MSW (2015): Obwieszczenie Ministra Spraw Wewnętrznych z dnia 3 lipca 2015 r. w sprawie ogłoszenia przejść granicznych, rodzaju ruchu dozwolonego przez te przejścia oraz czasu ich otwarcia. Monitor Polski, 2015: 636.

NATURAL EARTH (2021): Free vector and raster map data at 1:10m, 1:50m, and 1:110m scales. Natural Earth website [online]. [cit. 02.08.2021]. Available at: https://www.naturalearthdata.com/downloads

NERB, G., HITZELSBERG, F., WOIDICH, A., POMMER, S., HAMMER, S., HECZKO, P. (2009): Scientific report on the mobility of cross-border workers within the EU-27/EEA/EFTA countries [online]. [cit. 06.08.2021]. Available at: https://ec.europa.eu/futurium/en/system/files/ged/mkw_workers_mobility.pdf

NEWMAN, D. (2006): Borders and bordering: Towards an interdisciplinary dialogue. European Journal of Social Theory, 9(2): 171–186.

NILSSON, J. K. (2018): Mobility and regionalisation: Changing patterns of air traffic in the Baltic Sea region in connection with European integration. Geographia Polonica, 91(1): 77–93.

OPENSTREETMAP (2021): OpenStreetMap Data Extracts. Geofabrik GmbH website [online]. [cit. 02.08.2021]. Available at: https://download.geofabrik.de

OSZTER, V. (2019): How to establish and operate cross-border public transport in a peripheral rural area? The example of the central and southern section of the border between Austria and Hungary. Prace Komisji Geografii Komunikacji PTG, 22(1): 52–65.

PALMOWSKI, T. (2015): Transport lądowy i lotniczy Obwodu Kaliningradzkiego. Logistyka, 2015(3): 3692–3702.

PERENNES, P. (2017): Open access for rail passenger services in Europe: Lesson learnt from forerunner countries. Transportation Research Procedia, 25: 358–367.

PKP (1985): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 2.VI.1985–28.IX.1985. Warszawa, Wydawnictwa Komunikacji i Łączności.

PKP (1990): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 27.V.1990–29.IX.1990. Warszawa, Wydawnictwa Komunikacji i Łączności.

PKP (1991): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 2.VI.1991–28.IX.1991, Wydawnictwa Komunikacji i Łączności.

PKP (1992a): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 31.V.1992–26.IX.1992. Warszawa, Wydawnictwa Komunikacji i Łączności.

PKP (1992b): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 27.IX.1992–22.V.1993. Warszawa, Wydawnictwa Komunikacji i Łączności.

PKP (1993): Rozkład Jazdy Pociągów: Połączenia międzynarodowe, 23.V.1993–25.IX.1993. Warszawa, Wydawnictwa Komunikacji i Łączności.

PKP (1995): Rozkład Jazdy Pociągów Międzynarodowych, 24.09.1995–1.06.1996. Warszawa, Kolejowa Oficyna Wydawnicza.

PKP (2000): Międzynarodowy Rozkład Jazdy Pociągów, 28.05.2000–9.06.2001. Warszawa, Kolejowa Oficyna Wydawnicza.

PKP (2004): Sieciowy Rozkład Jazdy Pociągów, 12.12.2004–10.12.2005. Warszawa, PKP Przewozy Regionalne.

PKP (2009): Sieciowy Rozkład Jazdy Pociągów, 13.12.2009–11.12.2010. Warszawa, PKP Przewozy Regionalne.

PKP (2011): Sieciowy Rozkład Jazdy Pociągów, 11.12.2011–08.12.2012. Warszawa, Przewozy Regionalne.

PKP (2014): Sieciowy Rozkład Jazdy Pociągów, 14.12.2014–12.12.2015. Warszawa, PKP Polskie Linie Kolejowe.

PKP (2018a): Rozkład Jazdy Pociągów Międzynarodowych, 09.12.2018–09.03.2019. Warszawa, PKP Intercity.

PKP (2018b): Sieciowy Rozkład Jazdy Pociągów, 09.12.2018–14.12.2019. Warszawa, PKP Polskie Linie Kolejowe.

PLK (2021): Mapa inwestycji ujętych w Krajowym Programie Kolejowym. PKP Polskie Linie Kolejowe interactive map [online]. [cit. 10.08.2021]. Available at: http://plk-inwestycje.pl

PRZYBYCIŃSKI, T. (2009): Kształtowanie ładu gospodarczego w Polsce w kontekście integracji z UE. Prace i Materiały Instytutu Rozwoju Gospodarczego SGH, 82: 192–222.

ROIDER O., SAMMER G., RIEGLER S., KLEMENTSCHITZ, R., BEZAK B., BALKO G. (2018): Challenges of border-crossing transport demand surveys – methodical solutions and experiences with their organization to achieve high quality, an EU-perspective. Transportation Research Procedia, 32: 394–403.

ROSIK, P., KOMORNICKI, T., GOLISZEK, S., ŚLESZYŃSKI, P., SZARATA, A., SZEJGIEC-KOLENDA, B., POMIANOWSKI, W., KOWALCZYK,K. (2018): Kompleksowe modelowanie osobowego ruchu drogowego w Polsce. Uwarunkowania na poziomie gminnym. Prace Geograficzne, 267. Warszawa, IGiPZ PAN.

ROSIK, P., STĘPNIAK, M., WIŚNIEWSKI, R. (2020). Delineation of health care deserts using accessibility measures: the case of Poland. European Planning Studies, 29(6): 1151–1173.

ROSSTAT (2021): Chislo sobstvennykh legkovykh avtomobiley po sub'yektam Rossiyskoy Federatsii. ROSSTAT website [online]. [cit. 24.08.2021]. Available at: https://rosstat.gov.ru/storage/mediabank/DDFfgtCb/t3-4.xls

SANTOS, G., MAOH, H., POTOGLOU, D., VON BRUNN, T. (2013): Factors influencing modal split of commuting journeys in medium-size European cities. Journal of Transport Geography, 30: 127–137.

SHOPPINGPL.COM (2019): Litaky do Pol'shchi: rozklad rukhu ta tsiny na kvytky u 2019 rotsi. Shoppingpl website [online]. [cit. 04.08.2021]. Available at: https://shoppingpl.com/post/257-litaky-do-polshchi-rozklad-rukhu-ta-tsiny-na-kvytky-u-2019-rotsi

SKODLARSKI, J., PIECZEWSKI A. (2011): Przesłanki transformacji polskiej gospodarki 1990–1993, Studia Prawno-Ekonomiczne, 83: 379–395.

STATISTICS POLAND (2020a): Ruch graniczny oraz wydatki cudzoziemców w Polsce i Polaków za granicą w 2019 r. Warsaw-Rzeszów, Statistics Poland, Urząd Statystyczny w Rzeszowie [online]. [cit. 05.08.2021]. Available at: https://stat.gov.pl/obszary-tematyczne/ceny-handel/handel/ruch-graniczny-oraz-wydatki-cudzoziemcow-w-polsce-i-polakow-za-granica-w-2019-roku,15,6.html

STATISTICS POLAND (2020b): Populacja cudzoziemców w Polsce w czasie COVID-19. Warsaw, Statistics Poland [online]. [cit. 05.08.2021]. Available at: https://stat.gov.pl/statystyki-eksperymentalne/kapital-ludzki/populacja-cudzoziemcow-w-polsce-w-czasie-covid-19,12,1.html

STATISTICS POLAND (2021): Local Data Bank website [online]. [cit. 24.08.2021]. Available at https://bdl.stat.gov.pl/BDL/start

STUDZIŃSKA, D. (2019): Wybrane aspekty transformacji funkcji i stopnia przenikalności granicy polsko-rosyjskiej. Przegląd Geograficzny, 91(4): 553–571.

TAYLOR, Z. (2007): Rozwój i regres sieci kolejowej w Polsce. Monografie, 7. Warszawa, IGiPZ PAN.

TVN.24.pl (2022). Z Polski do Chorwacji jednym pociągiem – czy już w te wakacje ruszą połączenia z Krakowa do Splitu? TVN24.pl website [online]. [cit. 17.02.2022]. Available at: https://tvn24.pl/polska/pociag-z-polski-do-chorwacji-kiedy-ruszy-polaczenie-z-krakowa-do-splitu-planowany-rozklad-jazdy-5599527

VAROL, C., SÖYLEMEZ, E. (2017): Border permeability and drivers of cross-border cooperation in the Turkish and EU border region. EBEEC Conference Proceedings: The Economies of Balkan and Eastern Europe Countries in the Changed World, KnE Social Sciences: 87–98.

VERA REBOLLO, J. F., IVARS BAIDAL, J. A. (2009): Spread of low-cost carriers: Tourism and regional policy effects in Spain. Regional Studies, 43(4): 559–570.

VON ARX, W., VU, T. T., WEGELIN, P., MAARFIELD, S., FRÖLICHER, J. (2018): The development of international passenger rail services from 2007 to 2016: The case of Switzerland. Research in Transportation Economics, 69: 326–336.

VSETUTPL.COM (2019): Loukosty do Pol'shchi: napryamky, rozklad reysiv ta tsiny. Vsetutpl website [online]. [cit. 04.08.2021]. Available at: http://vsetutpl.com/loukosty-do-polschi-napryamky-rozklad-reysiv-ta-tsiny

WENDT, J. A. (2019): Geopolityczne uwarunkowania przenikalności granic i dyfuzji idei w Europie Środkowej. Przegląd Geopolityczny, 28: 31–48.

WIERING, M., VERWIJMEREN, J. (2012): Limits and borders: Stages of transboundary water management. Journal of Borderlands Studies, 27(3): 257–272.

WIĘCKOWSKI, M. (2003): Transgraniczne połączenia kolejowe na południowych granicach Polski na początku XXI w. Prace Komisji Geografii Komunikacji PTG, 9: 201–210.

WIĘCKOWSKI, M. (2010): Specific features of development of tourism within the areas neighbouring upon the Polish eastern border. Europa XXI, 20: 101–115.

WIĘCKOWSKI, M. (2019): Od barier i izolacji do sieci i przestrzeni transgranicznej – konceptualizacja cyklu funkcjonowania granic państwowych. Przegląd Geograficzny, 91(4): 443–466.

WIĘCKOWSKI, M., MICHNIAK, D., BEDNAREK-SZCZEPAŃSKA, M., … , WIŚNIEWSKI, R. (2014): Road accessibility to tourist destinations of the Polish-Slovak borderland: 2010–2030 prediction and planning. Geographia Polonica, 87(1): 5–26.

WILLIAMS, A. M., BALÁŽ, V., BODNÁROVÁ, B. (2001): Border regions and trans-border mobility: Slovakia in economic transition. Regional Studies, 35(9): 831–846.

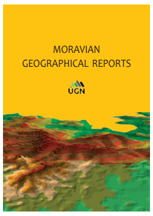
WIRTUALNEMEDIA.PL(2017): LOT uruchomił połączenie Warszawa – Kaliningrad. Wirtualnemedia.pl website [online]. [cit. 22.05.2021]. Available at: https://www.wirtualnemedia.pl/artykul/lot-uruchomil-polaczenie-warszawa-kaliningrad

WIŚNIEWSKI, R., KOMORNICKI, T. (2021): Przemiany międzynarodowej mobilności Polaków. Przegląd Geograficzny, 93(2): 161–180.

ZOPOT (2020): Sprawozdanie rok 2019. Zagraniczny Ośrodek Polskiej Organizacji Turystycznej w Moskwie. Polska Organizacja Turystyczna [online]. [cit. 22.05.2021]. Available at: https://www.pot.gov.pl/attachments/article/1804/ZOPOT%20Rosja%202019.pdf

Please cite this article as:

KOMORNICKI, T., WIŚNIEWSKI, R., KOWALCZYK, K. (2022): Modal split of passenger traffic: The Polish section of EU external borders. Moravian Geographical Reports, 30(2): 116–133. doi: https://doi.org/10.2478/mgr-2022-0008



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics

journal homepage: **http://www.geonika.cz/mgr.html**

doi: **https://doi.org/10.2478/mgr-2022-0009**

A comparison of the hydrodynamic characteristics of surface runoff generated by flash floods in geologically different areas of the Bohemian Massif (crystalline rocks) and the western Carpathians (flysch)

Vilém SPÁLOVSKÝ [a]*, Stanislav RUMAN [a], Milan TRIZNA [b]

Abstract

The geological environment is undoubtedly one of the basic factors that influence the formation of surface runoff. The extent to which this factor can also affect the hydrodynamic characteristics of flash floods, which is also indirectly associated with flood risk, is the main topic of this study. In two geologically different areas of the Bohemian Massif (crystalline rocks predominate) and the western Carpathians (flysch rocks predominate), a total of 40 watersheds characterised by sharing a certain hydrological analogy were selected (20 watersheds from the Massif and 20 from the Flysch zone). In each of these watersheds, 1-year, 10-year and 100-year flash flood return periods were constructed using the two-dimensional hydrodynamic model Iber. The outputs from this model included raster datasets of areas, depths, and flow velocities during inundations. Subsequently, these rasters were analysed and compared with an emphasis on differences within the individual geological study areas. The outputs showed clear differences in the individual hydrodynamic characteristics (e.g. the average inundation area during Q_{100} *was 29.07% larger in the Flysch than in the Massif). Overall, the Flysch zone appeared to be far riskier in terms of flash floods than in the case of the Bohemian Massif.*

Key words: *Flash floods, 2D hydrodynamic modelling, factors affecting floods, flood risk, Flysch zone, Bohemian Massif, Iber model, Czech Republic*

Article history: *Received 30 October 2021, Accepted 20 April 2022, Published 30 June 2022*

1. Introduction

According to European Commission (2006), we can describe floods as natural phenomena that causes the "temporary covering by water of land not normally covered by water". There are several possibilities for how such water coverage can occur and how the floods themselves are classified. In Europe, according to the HANZE (2017) database, we most often encounter riverine floods, i.e. floods that affect larger watercourses, mainly during periods of long-duration (> 1 day) rainfall or intense snow cover melt. Furthermore, we encounter so-called flash floods, which, in contrast, mainly affect small watercourses after short (< 1 day) and heavy torrential rains. In coastal areas, we encounter coastal floods, which most often occur because of storm surges.

In general, we can say that the floods in Europe are some of the most dangerous natural hazards that occur in the area (Gvoždíková and Müller, 2017; Kundzewicz et al., 2018). There have been several occurrences of this phenomenon in recent decades, with serious negative effects on the health, lives, and property of the inhabitants (Blöschl et al., 2020; Paprotny et al., 2018; UNDRR, 2019). The outlook for the future is also unfavourable. Winsemius et al. (2015) assume that climate change will lead to a significant increase in global flood risk, which cannot be avoided in Europe. This calls for more mitigation and adaptation measures and an overall better understanding of this phenomenon to reduce economic and especially human losses. This study strives to become a part of this conversation.

[a] Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, Czech Republic (*corresponding author: V. Spálovský, e-mail: *vilem.spalovsky@osu.cz*)

[b] Department of Physical Geography and Geoinformatics, Faculty of Natural Science, Comenius University, Bratislava, Slovakia

As many authors (e.g. Diakakis et al., 2020; Fragoso et al., 2012; Gaume et al., 2009; Sene, 2013) have shown, especially dangerous floods are caused by short-term (< 1 day), high-intensity precipitation events, predominantly of convective origin, that arise locally in small areas (< 100 km^2), i.e. flash floods (Bryndal, 2015; Marchi et al., 2010). In addition, this type of flood is problematic in terms of its extreme difficulty in forecasting (Vincendon et al., 2011). This is based on the accuracy of the measured data in real-time and the accuracy and temporal and spatial resolution of meteorological models and their forecast lead times, as well as the accuracy of hydrological models (Hapuarachchi et al., 2011).

At first glance, it is obvious that a combination of individual forecast components may introduce many errors and uncertainties that are not easy to address, although several techniques and innovations have been developed in recent years that significantly improve the forecasting of flash floods (Berkhahn et al., 2019; Mosavi et al., 2018; Zanchetta and Coulibaly, 2020). It is still not possible to predict all events with sufficient accuracy, especially events in small ungauged watersheds (Hapuarachchi et al., 2011; Ntelekos et al., 2006). Unfortunately, these small watersheds may also occur in heavily urbanised areas, where flash floods occur almost without warning and may have catastrophic consequences (Hardy et al., 2016).

To prevent or at least reduce these consequences, a variety of measures may help (e.g. Kreibich et al., 2015; Krzhizhanovskaya et al., 2011; Poussin et al., 2015). In addition to technical measures and various warning systems, flood hazard mapping and flood risk mapping play very important roles. Mapping enables us to identify critical areas for floods, pre-assess the level of risk in these areas and then make efforts to reduce the consequences of possible floods. According to Directive 2007/60/EC, a preliminary flood risk assessment is required for each EU member state for all types of floods, including flash floods. As the literature has indicated, several different methods are used for this purpose worldwide (e.g. Kandilioti and Makropoulos, 2011; Li et al., 2012; Wang et al., 2011). Nevertheless, only a few methods are used in conjunction with flash floods.

One of the few examples is the research of Zeleňáková et al. (2015), which described the preliminary assessment of flood risk from flash floods based on the so-called Critical Point Method (CPM). This method was derived by Drbal et al. (2009) after a series of catastrophic flash floods in 2009 in the Czech Republic. The CPM cannot be used as a stand-alone tool for the preliminary assessment of flood risks, however, as it only detects areas prone to flash floods based on selected physical-geographic characteristics and the presence of built-up areas (Štěpánková et al., 2017). By supplementing the CPM with a suitable risk analysis, we may obtain a relatively good method for the preliminary assessment of flash flood risks, even on a national scale, which fully complies with the requirements of Directive 2007/60/EC. In our study, the CPM was used as a tool for the selection of research sites, and it is described more specifically in the Materials and Methods section.

A crucial part of our work is hydrodynamic modelling. In recent decades, this modelling has become an integral part of flood risk management, and its outputs serve as tools for decision makers. There have been an increasing number of studies that use hydrodynamic models to determine flood risk (Baky et al., 2019; Dinh et al., 2012; Masood and Kuniyoshi, 2011), even in small ungauged watersheds (Li et al., 2019; Vojtek and Vojteková, 2016). Using hydrodynamic models, the hydrodynamic characteristics can be simulated, i.e. the area and depth of inundation and the velocity of flow. Using these characteristics, the degree of flood hazard is determined. Flood hazard is a fundamental component of the resulting flood risk. According to Wisner et al. (2004), we can simply formulate the resulting flood risk as a combination of vulnerability and flood hazard: Risk = Vulnerability × Hazard. Coupled hydrological models (or rainfall-runoff models) can also be used for more complex analyses. These models are coupled with hydrodynamic models and provide information about the shape of the flood wave (i.e. the flood hydrograph). This approach is used mainly in large-scale modelling (Paiva et al., 2013; Xia et al., 2019) but also in areas of ungauged watersheds (Li et al., 2019; Vojtek et al., 2019).

The propagation of floods can be affected by several factors (see Section 2.2), including the geological environment of the affected area, which may also contribute to some extent (Chen et al., 2020; Gutiérrez et al., 2014; Norbiato et al., 2009). We observe that methodologies for preliminary flood risk assessment are often applied nationwide, regardless of the various geological environments: we do not know to what extent these environments affect the resulting hydrodynamic characteristics of flash floods. In our study, we focus specifically on flash floods and demonstrate how geological settings can affect these characteristics and thus the resulting flood risk.

The main aim of this study is to respond to the following questions, which have not been discussed thus far:

- What is the resulting hydrodynamic behaviour of watercourses below the critical points?;
- Is there a real flood risk below all critical points and, if so, under what N-year return period (N-year flood scenario)?; and
- How can this behaviour differ regarding different quasi-homogeneous geological areas? This is the most important question.

For example, in the conditions of the Czech Republic, where in one part of the country (Bohemian Massif), there are mostly resistant crystalline rocks (but with aquiferous fractures), and in other parts, there are poorly permeable sedimentary rocks of the Flysch belt (western Carpathians). Much of the literature (Kourgialas and Karatzas, 2011; O'Connor et al., 2002; Spellman et al., 2019) has emphasised the fact that the geological environment may significantly contribute to the formation of riverine floods and thus form one of the basic factors that influence these events. We know that it can also affect flash floods in highly permeable rocks, i.e. in karsts, where a specific type of flash flood occurs (Bonacci et al., 2006; Gutiérrez et al., 2014; Zanon et al., 2010).

What has not been much described in the literature, however, is to what extent this factor can affect the nature of flash floods in strongly impermeable rocks such as flysch rocks. Not only in the case of the CPM but also in other similar methods, this geological factor is often omitted and not calculated. For this reason, we consider it desirable to find answers to the abovementioned questions so that in the future, we can make the CPM (and possibly other methods) a more credible and robust basis for preliminary flood risk assessment. We also aim to fill gaps in the understanding of this phenomenon.

2. Theoretical background

2.1 Hydrodynamic modelling

As outlined earlier, hydrodynamic models are a valuable aid in estimating the extent and nature of floods. The core elements of these models are mathematical-physical governing equations, which are based on the physical laws of conservation of mass, momentum, and energy. Individual modelling software usually employs two control equations: the continuity equation and the momentum equation (Liu, 2018). These equations can be used in various modifications, and it is only up to the modelling software what set of equations it offers. Simplified forms of the equations may give less accurate results; however, models using them may be stable and have shorter computational times (Brunner, 2016). Several modelling software programs, both commercial and open source, are used worldwide. Teng et al. (2017), in their review, present more than 30 well-known hydrodynamic modelling software programs that allow flood inundations to be modelled.

Individual models may differ further in terms of dimensionality. Commonly applied hydrodynamic models in flood simulations are one-dimensional (1D) (Mark et al., 2004; Masood and Takeuchi, 2012), dominantly two-dimensional (2D) (Ernst et al., 2010; Mihu-Pintilie et al., 2019) or coupled 1D / 2D (Patel et al., 2017; Seyoum et al., 2012). With the 1D approach, the movement of water is simulated in only one direction, perpendicular to the individual cross sections. The main advantage of this approach is shorter computational time and less demand for topographic data (Costabile et al., 2015). Its suitability is limited mainly to simple watercourses and events in which no overflow occurs (Patel et al., 2017; Srinivas et al., 2009). In contrast, the 2D approach allows one to simulate the flow of water in two directions within a predefined computer network. The significant advantage of this approach is that it can simulate the flow of water around various obstacles, such as buildings, which is exactly what is needed in flood inundation modelling (Neal et al., 2010; Schubert and Sanders, 2012; Petroselli et al., 2019). Another possibility is a combination of the above-mentioned approaches, where the 1D approach is used for the stream channel and the 2D approach is used for the adjacent floodplain, as was done, for example, by Patel et al. (2017).

Information on the peak discharge of a flood event with a certain return period serves as the basic input data for hydrodynamic flood modelling. These peak discharges are either determined based on time series from the measured data, can be calculated on the basis of regional empirical formulas or can be estimated using hydrological models. As an example, we present the work of Petroselli et al. (2019), who compare the regional method according to Dub (1957) with the outputs of hydrological models and describe how the individual approaches affect the resulting hydrodynamic modelling. Petroselli et al. (2019) also point to the development of the digital elevation model (DEM), which is another essential component that is necessary for hydrodynamic modelling and whose quality can significantly affect the results. A DEM is a continuous representation of bare earth, on which surface runoff is generated and subsequently transported during the hydrodynamic modelling process. DEM is an integral part of the model's governing mechanisms. Many authors (e.g. Bates et al., 1998; Baugh et al., 2013; Jarihani et al., 2015) report that DEM accuracy is the factor that can most significantly affect the results of hydrodynamic models. For detailed modelling, which is used, for example, in the case of small watercourses, it is necessary to use very accurate, LiDAR-based (Light Detection and Ranging) DEMs with the lowest possible spatial resolution (Vaze et al., 2010). As further reported by Vaze et al. (2010), a very good resolution for these purposes is approximately 1 m (DEM cell size 1 × 1 m).

2.2 Flash flood propagation and influencing factors

The propagation of a flash flood in the natural environment is influenced by several factors with which we can work to a certain extent in the modelling environment. Aside from meteorological factors, which are undoubtedly the main triggering mechanism of flash floods, physical-geographical and anthropogenic factors play important roles. As Hewlett and Hibbert (1967) stated for small watercourses, these are mainly the average slope of the watershed, land use and the pedological-geological conditions of the area. The average slope of the watershed affects the flow velocity. If the slope of the watershed increases, then the average runoff rate increases and the time of concentration decreases. This is reflected in the watershed by a faster increase in the peak flow, which results in larger peak discharges (Gray, 1964; Subramanya, 2008). Land use characteristics mainly affect the infiltration capacity of soils and create a retarding effect for overland flow (Subramanya, 2008). Changes in land use may significantly cause a change in the flood flow regime (Brath et al., 2006). Some studies have reported that changes in land use may modify the average annual flow by 10% (Huisman et al., 2009; Li and Wang, 2009; Ruman et al., 2020).

Even geological characteristics, however, can be crucial in terms of the formation of the resulting flood event. To a certain extent, they influence the previously described physical-geographic factors and thus have a significant indirect effect on flood wave propagation. The geological setting of a given area affects, for example, the height of the erosion base level of a given watercourse (Kukal, 2005). Furthermore, the geological setting affects the morphology of the watercourse (width, depth, sinusoid, etc.) and the entire river network, which is due to the resistance of rocks and the properties of river sediments (Schumm, 1960; Schumm, 1985). These morphological factors determine the efficiency of a river basin to attenuate flood waves (Gray, 1964). Lithology also affects roughness conditions as well as the amount and properties of river sediments. It also plays a unique role in soil-forming substrates, that affects pedogenetic factors (e.g. infiltration). From this point of view, the most important role is played by superficial geology (Ruman et al., 2020). Direct effects are also notable due to the formation of a hydrogeological environment, which can have a significant retention capacity (Lauber et al., 2014; Spellman et al., 2019).

3. Material and Methods

3.1 Critical points method

Because torrential rains in Europe usually affect a very small area in a short period of time, their spatial and temporal prediction is considerably complicated. Also problematic is determining the intensity of torrential rain, which governs the issuance of warning information by the flood forecasting service, despite the relatively dense network of precipitation stations. Therefore, the prior identification and evaluation of critical points where there is a potential risk of flash floods is approached to ensure the elimination of negative consequences. For this purpose, the so-called critical points method is used in the Czech Republic as a suitable "national" strategy to reduce the risk of torrential rain (Novák and Tomek, 2015; Drbal et al., 2009).

Drbal et al. (2009) developed a nationwide survey for this purpose, the output of which is a point layer showing the critical points of inflow of storm water into an urban area with municipalities, and an area layer of the contributing watershed belonging to each point.

The procedure for locating individual critical points follows Drbal et al. (2009) and Štěpánková et al. (2017) and is as follows:

First, it was necessary to generate flow accumulation paths using a digital terrain model (10 × 10 m) and GIS tools (ArcHydro). The first set of critical points was identified in areas where these paths intersect with the boundaries of urban areas (for example, see Fig. 1). The individual critical points were also assigned an appropriate contributing area, for which the following physical-geographic characteristics were calculated: size of the contributing area, average slope, proportion of arable land area and the so-called critical condition index (CI).

The critical condition index was calculated according to the following formula:

$$C_I = A \cdot P \cdot (w_1 \cdot m + w_2 \cdot PAL + w_3 \cdot CN_{II}) \qquad (1)$$

where C_I is the index of critical conditions; A is the relative value of the size of the contributing area (with respect to a maximum considered size of 10 km^2) [-]; P is the relative value of the total one-day precipitation with a repetition period of 100 years for the territory of the Czech Republic (with respect to a maximum of 285.7 mm) [-]; w is the weight vector [1.48876; 3.09204, 0.467171]; m is the average slope of contributing area [%]; PAL is the proportion of arable land in the area [%]; and CN_{II} is the value of CN_{II} for the territory of the Czech Republic, which represents characteristics of the contributing area in consideration of run-off.

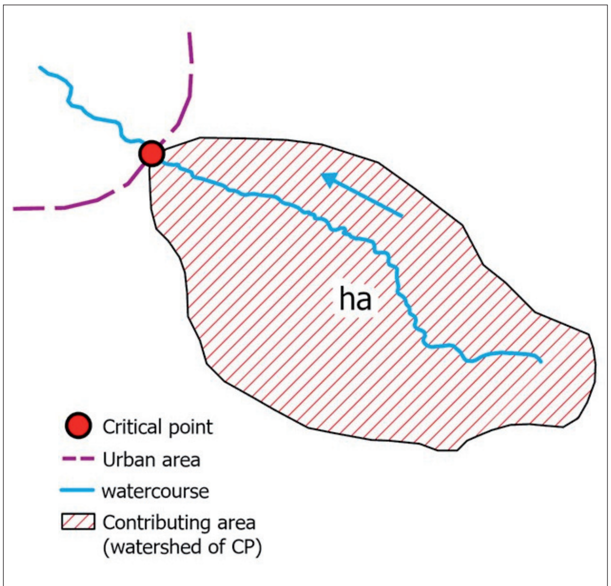


Fig. 1: Example of a critical point and its contributing area. Source: authors' compilation

The next step was the selection of critical points based on the criteria that were determined based on observations after flood events in the Czech Republic in 2009 and are as follows:

i. The size of the contributing area is in the range of 0.3–10 km^2;

ii. The average slope of the contributing area ≥ 3.5%;

iii. The proportion of arable land area ≥ 40%; and

iv. The critical condition index ≥ 1.85.

The results of this method included the determination of 9,261 geolocated critical points and their contributing areas throughout the Czech Republic. We used these points and areas in our research to determine and localise the study areas (Drbal et al., 2009; Štěpánková et al., 2017).

3.2 Selection of study areas

Immediately below each critical point, a certain area exists where a flood can have a negative effect on the life, health, and property of the inhabitants. These areas are exactly the goal of our study. Given that a large number of critical points were identified, research, in terms of time, personnel and finances, could not be conducted in all these locations. Therefore, it was necessary to select a small but representative sample, which was subsequently investigated.

From the national dataset of all critical points, 20 points from a geological area in the Bohemian Massif and 20 points from a geological area in the Flysch zone were selected (for an overview of characteristics: see Fig. 5 in Results section, below; for localisation: see Fig. 2). The selection was made using a geoinformation system in such a way that the individual contributing areas of the critical points (watersheds of individual critical points, for example see Fig. 1) had similar characteristics regarding area size, slope and share of arable land to the greatest extent possible (see Fig. 5, below). This was achieved by multiple point filtering using the structured query language. The individual points, which differed significantly from the rest of the dataset, were gradually erased until only 20 points remained in each of the geological areas. The resulting points were thus as similar as possible in all observed characteristics. This reduced the contributions from other factors affecting the character of surface runoff and, conversely, emphasised the geological environment.

For each critical point, we subsequently determined N-year return periods (1-yr, 10-yr and 100-yr), which served as basic input data for two-dimensional hydrodynamic models.

3.3 Determination of values of individual N-year return periods

The calculation of single N-year return periods was carried out by using an hydrological analogy method. In the individual geological areas in the Massif and Flysch, we selected a group of stream gauging stations with the smallest possible contributing area so that they corresponded as closely as possible to our examined catchment area of critical points. The area of selected gauged catchments was within the range of 4.1–28.9 km^2. Subsequently, freely available data (N-year return periods) were obtained from the Czech Hydrometeorological Institute (hereinafter CHMI). CHMI is computes N-year return periods from annual maximal flows and/or proxy data of historical floods (where available) and uses three various statistical distributions. The selection of a particular distribution is based on expert estimates. In the next step, the average of these N-year flows ($\varnothing Q_N$) was calculated, and the average area of the watershed

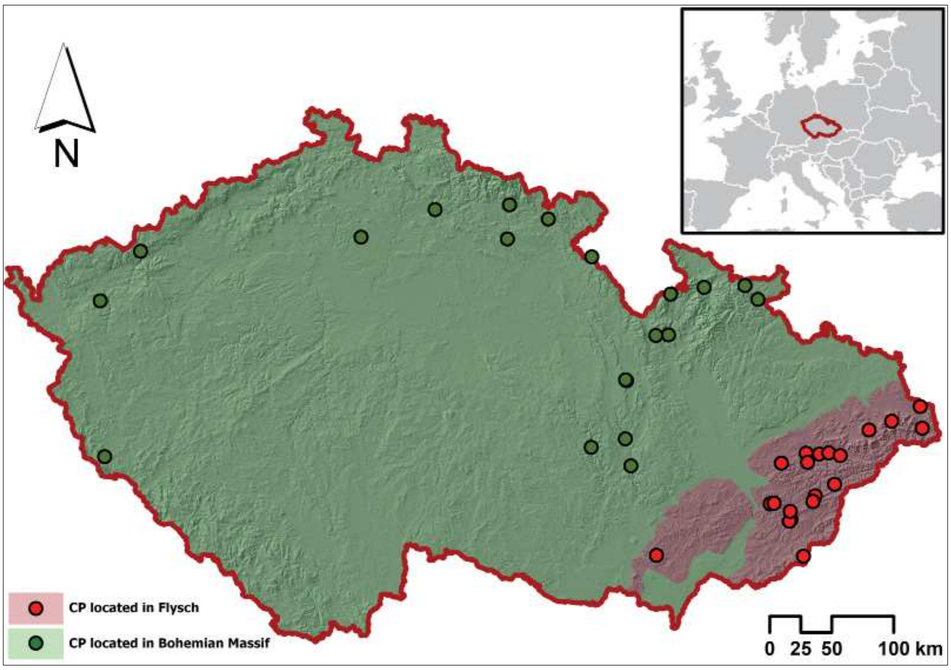


Fig. 2: Selected critical points (CP) within the Czech Republic and their distribution according to the relevant geological area
Sources: Eurostat, EU-DEM, GeoCR500, and authors' compilation

($\varnothing A$) belonging to the gauging stations was calculated. By dividing $\varnothing Q_N$ by $\varnothing A$, we obtained a coefficient by which we continued to multiply the areas of critical point watersheds (A_i), based on which we obtained missing information about the required N-year discharges in our critical point catchments.

The values of individual $\varnothing Q_N$ and $\varnothing A$ for the Massif and Flysch are presented in the Results section in Table 2, and the calculation is schematised by the following equation:

$$Q_{N_i} = A_i \cdot \frac{\varnothing Q_N}{\varnothing A} \tag{2}$$

3.4 Process of hydrodynamic modelling

For modelling, we selected the freely available Iber software version 2.5.2., which, according to Pinos and Timble (2019), shows very good results in mountain basin areas, and this corresponded exactly to our research areas. In addition, it turned out that the calculation of the Iber model was much more stable for our research areas than, for example, the HEC-RAS model, where there were problems with model stabilisation. The Iber model can automatically adjust the computational time (even less than 0.1 s) to satisfy the Courant condition, which makes it a very good and stable tool that is more suitable for our conditions. This model has also appeared very often in the literature in connection with two-dimensional hydrodynamic (2D HD) modelling in flash flood conditions (e.g. Bodoque et al., 2016; Garrote et al., 2016; Ruiz-Villanueva et al., 2014a).

As reported by Bladé et al. (2014), the Iber model is a two-dimensional numerical model used to simulate turbulent free surface unsteady flow and other environmental processes in stream hydraulics. For our case, i.e. modelling the area and depth of inundation and flow velocities, we used a hydrodynamic module, which uses the finite volume technique to solve the 2D shallow water equations (2D Saint-Venant Equations).

The governing equations represent a set of partial differential equations that describe the conservation of mass and momentum in the two horizontal directions as shown below (Bladé et al., 2014; Hydraulic Reference Manual Iber v1.0, 2014):

$$\frac{\partial h}{\partial t} + \frac{\partial hU_x}{\partial x} + \frac{\partial hU_y}{\partial y} = M_S; \tag{3}$$

$$\frac{\partial hU_x}{\partial t} + \frac{\partial hU_x^2}{\partial x} + \frac{\partial hU_xU_y}{\partial y} = \tag{4}$$

$$= -gh\frac{\partial Z_s}{\partial x} + \frac{\tau_{s,x}}{\rho} - \frac{\tau_{b,x}}{\rho} - \frac{g}{\rho} + \frac{h^2}{2}\frac{\partial \rho}{\partial x} +$$

$$+ 2\omega \sin \lambda U_y + \frac{\partial h\tau_{xx}^e}{\partial x} + \frac{\partial h\tau_{xy}^e}{\partial y} + M_X;$$

$$\frac{\partial hU_y}{\partial t} + \frac{\partial hU_xU_y}{\partial x} + \frac{\partial hU_y^2}{\partial y} = \tag{5}$$

$$= -gh\frac{\partial Z_s}{\partial y} + \frac{\tau_{s,y}}{\rho} - \frac{\tau_{b,y}}{\rho} - \frac{g}{\rho} + \frac{h^2}{2}\frac{\partial \rho}{\partial y} -$$

$$- 2\omega \sin \lambda U_x + \frac{\partial h\tau_{xy}^e}{\partial x} + \frac{\partial h\tau_{yy}^e}{\partial y} + M_Y$$

where t is time; x and y represent the directions of the Cartesian coordinate system used; h is water depth; U_x and U_y are depth-average horizontal velocities; g is the acceleration of gravity; Z_s is free surface elevation; τ_s is the friction on the free surface due to friction produced by wind; τ_b is the friction at the bottom; ρ is the density of the water; ω is the angular velocity of the Earth's rotation; λ represents the latitude of the studied point; τ^e_{xx}, τ^e_{xy} and τ^e_{yy} are the effective horizontal shear stresses; and M_s, M_x and M_y are the terms of mass source and momentum, which are used to model precipitation, infiltration and drainage.

The model was developed downstream of all localities (critical points). Equal lengths of watercourses were established at 300 m. The mean slope of the watercourses in the Bohemian Massif was 0.036 m/m with a standard deviation of 0.017. For the Flysch streams, these values were 0.031 and 0.011 for the mean and standard derivation, respectively. As the morphology of the floodplain is also important in flood hazard studies, we calculated the mean width of the floodplain, where the floodplain was considered an area equal to the borders of the Q_{100} inundation area. The mean value was calculated in ArcGIS Pro, creating stream centreline, and automatically creating a cross section every 10 metres. Then, the mean value and standard deviation were calculated.

3.5 Topographic data

The basic topography is represented using a digital elevation model (DEM) DMR 5G obtained from the Czech Office for Surveying, Mapping and Cadastre. This DEM was created by laser scanning for the entire territory of the Czech Republic and has a high resolution of 1 × 1 m with a mean height error of up to 0.18 m (ČUZK, 2021). Due to the lack of information regarding the shape of cross-sections, we decided to leave the bathymetry of watercourses unchanged without making any corrections. We only filtered out transverse obstacles such as bridges and culverts, so that the stream channel allows the flow of Q_{100} at the location of the obstacle. The deviation of bathymetry can introduce small uncertainties into the results of the 2D HD model (for more details, see Section 5: Discussion, below); however, the topographic conditions were the same for all research sites, and the results of the comparison of outputs were not affected to any large extent.

For the needs of our research, it was still necessary to add volumes of buildings to the DEM, so that the flow around the individual buildings during inundation was resolved. For this purpose, we used building polygons from the Open Street Map project (OpenStreetMap®, 2019), to which we then assigned a uniform height using a GIS application and converted them to raster data. We continued to merge the raster volumes of the buildings with the DEM, thus creating a pseudo digital model of the surface, i.e. the relief + building model but without vegetation cover (an example is shown in Fig. 3). We used the pseudo digital surface model created in this way as input topographic data, based on which an irregular triangular computational network was generated in the Iber model (length of triangle edge ≤ 1 m).

3.6 Roughness coefficient

For the model to calculate an important input parameter, bed friction (τ_b), it was necessary to know the value of the so-called bed friction coefficient (C_f). For this purpose, the model used the Iber Manning equation in the following form (Hydraulic Reference Manual Iber v1.0, 2014):

$$C_f = g\frac{n^2}{h^{\frac{1}{3}}} \tag{6}$$

where g is the gravity acceleration; h is the depth and n is the Manning roughness coefficient that needs to be entered manually. For our case, we entered a uniform value of 0.06 for all research sites, so that the same conditions were

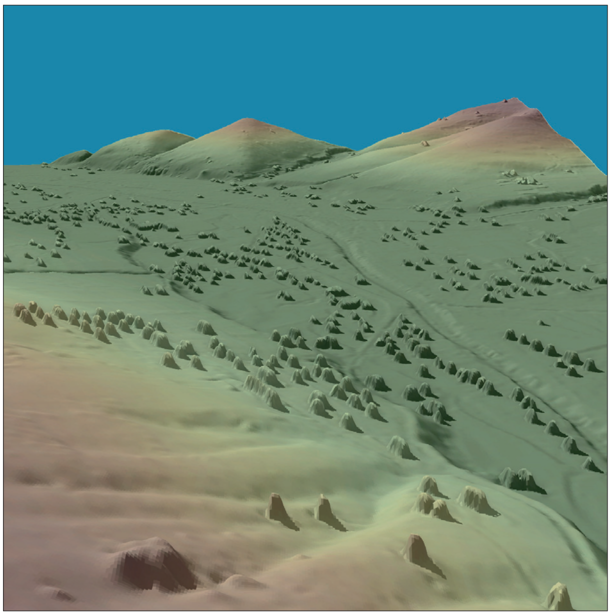


Fig. 3: Example of pseudo digital surface model used in this work as input topography to the 2D HD models
Sources: authors' compilation based on Open Street Map data and DMR 5G

maintained. We estimated this value based on a manual by Arcement and Schneider (1989) with regard to the similarity of individual research sites.

3.7 Other parameters in the model

Other settings of the 2D hydrodynamic model included the selection of a numerical scheme, where we chose the 2nd-order scheme, which is slower to calculate and less stable, but the outputs are much more accurate. Initial conditions were considered without prior water contribution (initial depth = 0 m). The overall settings are presented in Table 1. With this model setting, depth and flow velocity rasters at a 1 × 1 m resolution were calculated for each N-year scenario (Q_1, Q_{10} and Q_{100}) for each research area.

3.7 Flood risk assessment – endangered area

To determine whether there is a potential occurrence of flood risk below certain critical points and possibly how this occurrence differs in the Flysch and Massif, we created a very simple method of so-called endangered areas. The endangered area represents the area of buildings in which the inhabitants may reside or where their property may be, and at the same time this area intersects the area of inundation of a certain N-year scenario. During a particular flood scenario, a certain risk may occur in such an endangered area. In this method, however, we did not quantify the degree of risk: we only determined in a binary metric whether a potential risk may occur and, if so, to what extent.

With the settings of the model presented in the previous steps, rasters of depths and water flow velocities at a resolution of 1 × 1 m were calculated for individual N-year scenarios (Q_1, Q_{10} and Q_{100}) for each research area (a total of 240 raster outputs). The models differed only in input topography and input flow values. For completeness, the area of flow velocities greater than 1 m.s^{-1} and the area of depths greater than 1 m were added. This represents areas where more significant manifestations of flash floods occur. All post-processing with raster data was performed in the software application ArcGIS Pro.

Iber model settings	Choice
Module	2D hydrodynamic module
Computational network	Irregular triangular network with a resolution of 1 × 1 m
Topography	Modified DMR 5G (1 × 1 m)
Roughness	Based on Manning roughness coefficient with value of 0.06
Numerical Scheme	2^{nd}-order
Inlet	Total discharge of individual N-year return periods (in the form of steady flow)
Initial conditions	Depth (0 m)
Upper boundary condition	Total discharge (one value for a given N-year return period)
Result exportation	Rasters of water depths and velocities in a resolution of 1 × 1 m (Nearest-neighbour interpolation)

Tab. 1: Overview of the resulting settings of the Iber model in version 2.5.2. for 2D HD modelling in this study
Source: authors' compilation

4. Results

Table 2 presents the average N-year discharges and average contributing area derived from gauging stations. For completeness, we added information on the average annual rainfall and the average slope in the gauging station watersheds. Table 3 presents the average values of discharges obtained using the hydrological analogy method in individual geological areas and their differences within individual return periods. This average was calculated based on the resulting input flow data, presented in Table 2. At first glance, there are already differences in the hydrological behaviour of small streams between the Flysch and Massif. The streams below CP in the Flysch zone show 36.03% higher values of discharges at Q_1, 37.84% at Q_{10} and 32.97% at Q_{100}.

Under these conditions, the differences in the output rasters of depths and water flow velocities are also obvious. This is evidenced by a graphical representation in the form of boxplots (see Fig. 4) and representation in the form of a table with values of absolute and percentage differences of individual outputs, for individual modelled N-year return periods: see Table 4.

	∅Q_1 [$m^3.s^{-1}$)]	∅Q_{10} [$m^3.s^{-1}$)]	∅Q_{100} [$m^3.s^{-1}$)]	∅A [km^2]	∅Annual Rainfall [mm]	∅Slope [%]
Bohemian Massif	4.73 ± 2.16	17.30 ± 5.63	40.26 ± 12.25	18.28 ± 6.61	979 ± 143	13.8 ± 2.4
Flysch Zone	7.15 ± 3.35	26.94 ± 10.22	58.12 ± 17.97	17.89 ± 6.44	1,020 ± 109	15.9 ± 3.4

Tab. 2: Average N-year discharge and average contributing area in individual geological areas obtained from gauging stations. Sources: Input data from the Czech Hydrometeorological Institute; authors' calculations
Note: "±" denotes standard deviation (number to the right of this symbol)

Table 4 shows that the average inundation area of flash floods is larger in the Flysch in all examined N-year return periods. At Q_1 it is 31.74% larger; at Q_{10} it is 34.7% larger; and at Q_{100} it is 29.07% larger than those in the Bohemian Massif. These values are like the magnitude of differences in average discharges shown in Table 2. There are also larger average water depths in the Flysch which increase with increasing recurrence interval, where the largest percentage difference is observed in Q_{100} (16.11%), followed by Q_{10}(14.4%) and Q_1 (7.88%). In contrast, the Massif has slightly higher average flow velocities, which are 8.62% higher at Q_1, 2.8% higher at Q_{10} and 4.94% higher at Q_{100}. A clear pattern was not found when comparing differences in the magnitude of return periods and values of average flow velocities. The situation is diametrically different, however, if we examine only average areas where the flow velocity exceeds 1 $m.s^{-1}$. These areas are characterised by increased flood extremities and may have an increased flood risk. Such areas dominate in the Flysch, where the largest differences are observed at Q_{100} (20.08%) and Q_{10} (20.63%). During Q_1, they predominate by only 6.18%. Large fluctuations are represented by the average areas of depths greater than 1 m, where the Flysch prevails only in the case of extreme flow Q_{100} by 30.94%. During Q_{10}, the average areas of depths greater than 1 m already prevail in the Massif, namely, by 7.9%, and during Q_1, they prevail by 33.04% (see further discussion in Section 5, below).

	∅Q_1 [$m^3.s^{-1}$)]	∅Q_{10} [$m^3.s^{-1}$)]	∅Q_{100} [$m^3.s^{-1}$)]
Massif	0.40	1.45	3.37
Flysch	0.62	2.33	5.03
Diff.	0.22	0.88	1.66
Diff. (%)	36.03	37.84	32.97

Tab. 3: The resulting average discharges of individual N-year return periods obtained by the hydrological analogy method. Source: authors' calculations
Note: Diff. and Diff. (%) were computed between Q_N of Flysch and Massif. Q_N denotes the discharge with certain N-year return period

The mean width of the floodplain (see Fig. 5) was 29.51 m in Flysch, with a standard deviation of 14.01. Lower values were reported in the Massif: 22.07 and 10.53 for the mean and standard deviation, respectively.

The interquartile range (IQR) as a measure of dispersion was higher in the Flysch watershed in all scenarios for the area of inundation and the area of depths > 1 m, than in the Massif. For the water depth, Flysch watersheds had a higher IQR for Q_1 and Q_{10} but a lower IQR for Q_{100} than the Massif watershed. Dispersion was higher in the Massif for all scenarios of flow velocity and for scenarios Q_1 and Q_{10} for an area of velocities > 1 m.s^{-1} (Fig. 4).

Table 5 describes the outputs from the endangered area method for scenarios Q_{100} and Q_{10} (at Q_1 the endangered area is negligible). The table shows that the largest endangered area below critical points within our research sites is in the Flysch zone, both during Q_{100} (almost 57% more) and Q_{10} (almost 71% more). The table also shows the total number of research sites in which at least some unquantified risk is demonstrated using 2D HD models. Most such sites are again in the Flysch, where at Q_{100}, there are 16 areas (in 4 cases, the model did not confirm any flood risk) and at Q_{10} there are 11 areas (in 9 cases, the model did not confirm any flood risk).

		Area of inundation [m^2]	Water depth [m]	Flow velocity [m.s^{-1}]	Area of velocities > 1 m.s^{-1} [m2]	Area of depths > 1 m [m^2]
Q_1	Massif	2,854.60	0.19	0.49	225.50	113.35
	Flysch	4,182.05	0.21	0.45	240.35	85.20
	Diff.	1,327.45	0.02	– 0.04	14.85	– 28.15
	Diff. (%)	31.74	7.88	– 8.62	6.18	– 33.04
Q_{10}	Massif	4,113.75	0.23	0.72	743.85	140.75
	Flysch	6,302.45	0.27	0.70	937.15	130.45
	Diff.	2,188.70	0.04	– 0.02	193.30	– 10.30
	Diff. (%)	34.73	14.40	– 2.80	20.63	– 7.90
Q_{100}	Massif	5,874.25	0.26	0.90	1,427.70	162.80
	Flysch	8,281.45	0.31	0.86	1,786.45	235.75
	Diff.	2,407.20	0.05	– 0.04	358.75	72.95
	Diff. (%)	29.07	16.11	– 4.94	20.08	30.94

Tab. 4: The resulting values of individual hydrodynamic characteristics under different N-year return periods and their comparison within different areas of the Flysch and the Massif. Source: authors' calculations
Note: Differences were computed between Flysch and Massif. Q_N denotes the discharge with certain N-year return period

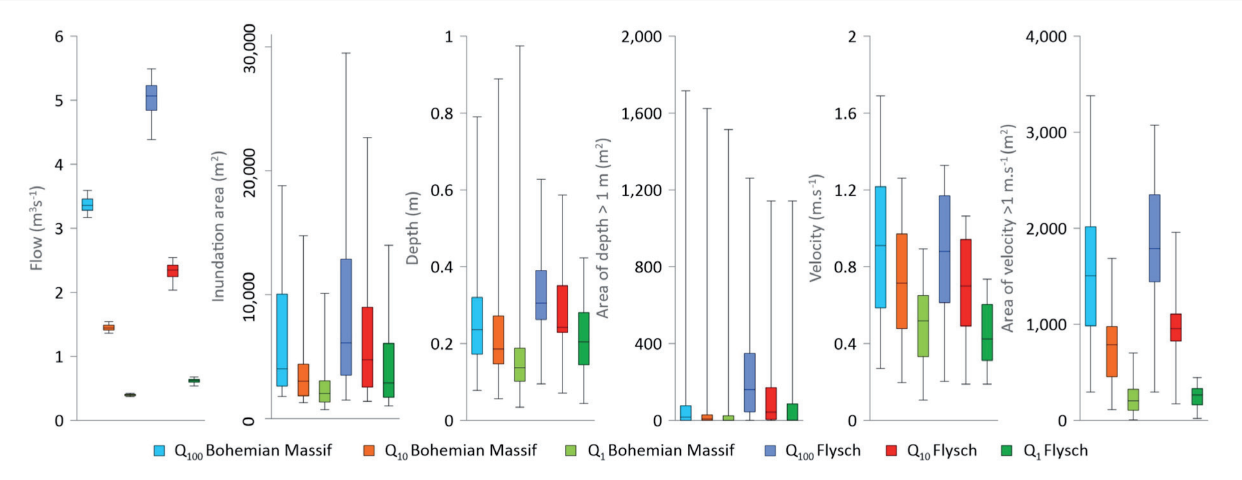


Fig. 4: Hydrodynamic characteristics of flash floods during different flood scenarios in different geological areas of the Flysch and the Massif. Graph whiskers indicate minimum and maximum values. The upper bound of the boxplot indicates Q_3, and the lower bound of the boxplot indicates Q_1. The median is used as a measure of central tendency
Source: authors' calculations

	Massif Q_{100}	Flysch Q_{100}	Massif Q_{10}	Flysch Q_{10}
∑ Endangered area [m^2]	7626.34	17534.89 (56.6% larger)	2994.29	10292.8 (70.9% larger)
Number of research sites with potential flood risk (out of 20)	14	16 (12.5% larger)	7	11 (63.6% larger)

Tab. 5: The size of endangered areas (within research sites) and the total number of research sites with a potential occurrence of flood risk in different conditions in the Flysch and Massif
Source: authors' calculations

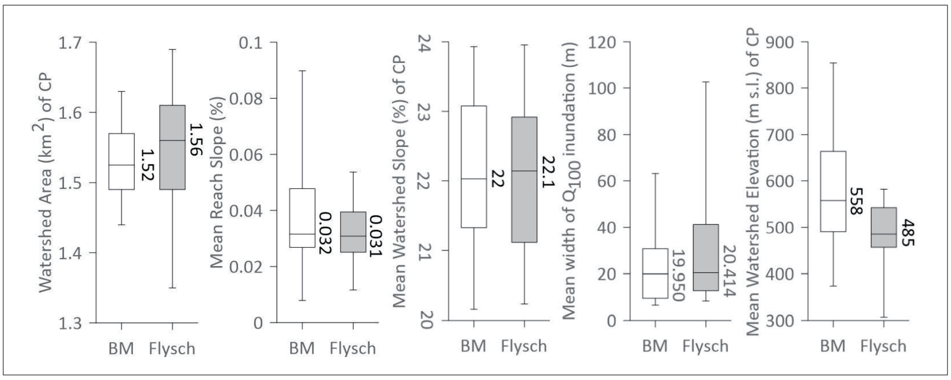


Fig. 5: Comparison of characteristics of selected critical points (respectively their watersheds). For better comparison, added information about mean reach slope and mean width of Q_{100} inundation (downstream of CP)
Source: authors' calculations

5. Discussion

5.1 Hydrodynamic modelling

As part of the methodological procedure, we determined the value of the Manning roughness coefficient based on the manual from Arcement and Schneider (1989). It must be said that in the case of the construction of precise and detailed 2D HD models, it is necessary to further adjust the values selected in this way during the process of calibration and validation of the model using real observed data. An example is the work of Pestana et al. (2013), in which the authors focused on the calibration of the model using the difference between the simulated inundation and the real inundation obtained from remote sensing images (using SAR). In their case, the optimal value of the Manning roughness coefficient was found to be 15% higher than the predetermined value. A more common method is to calibrate the model based on the observed water levels or discharges obtained from gauging stations. A typical example is the work of Smolders et al. (2012), in which the authors used both approaches. In our case, however, such a step could not occur due to the absence of gauging stations at our research sites or the lack of knowledge regarding historical floods. It was not even desirable, however, because our primary purpose was not to create precise 2D HD models, but models that have the closest possible conditions so that we can then evaluate them based on the hydrodynamic behaviour of streams within the different geological areas. Therefore, we applied a uniform value of the Manning roughness coefficient (n = 0.06) in all modelled areas.

Subsequently, we tried to evaluate the uncertainty that can be caused by different roughness values in real conditions. Ruman et al. (2021) also faced a similar problem in their work. They proceeded by choosing a method of repeated modelling with 6 different values of the Manning roughness coefficient (differing by one hundredth) and then determining a range of peak flows at individual roughness values, which differed by up to 40% in total. In our work, we also decided to use repeated modelling with a different value of the Manning roughness coefficient (specifically, n = 0.04), to compare the areas of inundations at different values of n. It turned out that the differences in the inundation areas of the output rasters modelled with a value n = 0.06 and rasters modelled with a value n = 0.04 of the Manning roughness coefficients are within a range of 5%. We believe that this indicates that the influence of Manning values did not change the main results of this study; indeed, the uncertainty in Manning values remains, as noted in previous studies.

Not only hydrodynamic modelling, but also any other environmental modelling is burdened with several uncertainties, and it is necessary to think critically when assessing the results (Beven, 2009). The same is true in our study. In addition to the uncertainties that stem from the lack of model calibration, these also include primarily the uncertainties associated with the digital elevation model. As mentioned by Papaioannou et al. (2016), DEM accuracy plays one of the most important roles in the modelling process. Although we chose the most accurate, commercially used elevation model for the Czech Republic, DMR 5G with a resolution of 1 × 1 m, this model can still be burdened with a mean error of height of up to 0.18 m (ČUZK, 2021). Another limitation of DMR 5G is the method of its construction, i.e. the use of infrared radiation for the detection of individual height points on the relief. Infrared radiation is largely absorbed by water, which can cause deviations in watercourse bathymetry.

Nevertheless, we believe that these deviations are not too large because sensing was performed on clear days with minimal cloud cover; therefore, we assume that water levels in our research streams were not above average and only reached a few cm. During the dry parts of the year, some streams may even be almost free of water; therefore, they do not constitute an obstacle to the passage of infrared radiation. Furthermore, it must be emphasised that our models do not consider the transport of sediments or other floating debris or ice (e.g. tree logs, trash or ice floes). These objects can clog the cross-section in places with obstacles on the watercourse (e.g. under bridges) and thus cause inundation even in places other than those shown in the models. More on this issue was presented, for example, by Ruiz-Villanueva et al. (2014b), who even modelled a situation where the water level increased by several metres due to a clogged cross-section, which our models would not have captured.

In addition, all transverse objects in watercourses (bridges and culverts) were removed from our DEM, which, according to many authors, are the main places that limit water runoff (Pappenberger et al., 2006; Diehl, 1997; Ruiz-Villanueva et al., 2012). All of this can cause some differences between real inundations and those modelled. Importantly, for all our modelled areas, a DEM created under the same conditions was applied, i.e. the individual models were burdened with the same uncertainties; thus, the results of the comparison of outputs are likely not affected to any great degree.

5.2 Discussion of results

We can already observe considerable differences in runoff between the Flysch and the Massif, based on the outputs from the hydrological analogy method (input values of N-year discharges: see Tab. 3). Each watershed examined in this study was not gauged, however. Thus, no observed hydrological data were available, and the flow values for each scenario were calculated from the return period of analogue gauged watersheds within the same geological group. The criteria for the selections of gauged watersheds were the geological formation, watershed area, watershed slope and proportion of arable land. This was indeed a crucial procedure that influenced the results of this study. Although this method is commonly applied (Petroselli et al., 2019), it should be noted, that hydrological behaviour (e.g. return periods) of large (average area is approximately 18 km^2), gauged watersheds are transformed to the behaviour of smaller (average area is approximately 1.5 km^2), ungauged watershed. This simplification was applied due to the limited number of small, gauged watersheds, meaning that both large and small catchments have equal hydrological response, which is certainly not true, especially when connected with geological characteristics. Thus, the differences between the hydraulic characteristics simulated in this study should be considered maximal diferences. More methods should be employed, such as rainfall-runoff modelling (Młyński, 2020) or artificial neural networks (Filipova et al., 2022), to calculate the return periods and examine the hydraulic behaviours in two geologically different areas to support the findings in this article.

If we examine the 100-year scenario, then we can say that the discharges are higher in the Flysch, on average by up to 32.9%. The same proportion does not prevail for individual HD characteristics. The percentage difference in the case of the inundation area compared with the inlet discharges decreases slightly, which is, however, reflected in the larger average depths of the inundations in the case of the Flysch. Larger inundation areas and at the same time greater water depths during individual N-year scenarios in the Flysch, nevertheless, significantly increase the value of the wetted perimeter. Due to friction, there is a greater kinetic loss of flowing water in the Flysch zone, which is reflected in lower average flow velocities. Even watercourses in the Massif achieve higher average flow velocities in individual N-year scenarios than in the Flysch zone.

Another reason why the water depth and velocities had opposite behaviours in the same geological areas (in Flysch higher water depths and lower water velocities) can be related to the mean width of the floodplain and slope of the stream (see Fig. 5). The results showed that higher values of the mean floodplain width were found in Flysch than in the Massif (the difference was 25.2%). Thus, the flow is more concentrated in Massif watersheds; therefore, velocities were higher. The width of the floodplain was calculated from the inundation area, however, and it demonstrated a clear connection with the input flows which influenced the results. Thus, more methods of floodplain delineation should be envisaged (Clubb et al., 2017) to confirm this conclusion. Furthermore, a higher stream slope was reported in the Massif watershed (13.89%), which further increases this contradictory behaviour. This situation is, however, diametrically different in the case of areas with velocities larger than 1 $m.s^{-1}$. In the Flysch, running water (especially during Q_{100} and Q_{10}) is concentrated in a larger stream tube, and areas with flow velocities greater than 1 $m.s^{-1}$ are thus significantly larger than those in Massif. If such a stream tube intersects with a built-up area, its kinetic energy can cause considerable damage and thus significantly increase the potential flood risk. Furthermore, areas with depths greater than 1 m have considerable fluctuation. This fluctuation, however, is because in the case of some research sites, depths greater than 1 m do not appear at all; therefore, the resulting area of depths greater than 1 m may be zero in some cases. Consequently, with decreasing input flow, these "zero" areas increase. This causes the resulting arithmetic mean to be significantly affected by these outliers. A better choice is to use a different measure of central tendency; in our case, we used the median, which in this case is a more reliable statistical representation. The percentage difference of the median of areas with a depth > 1 m is then always greater for the Flysch than for the Massif, as follows: at Q_1 by 50%, at Q_{10} by 85% and at Q_{100} by up to 90%. The medians for all output rasters are presented within the boxplots in Figure 4.

Many authors (e.g. van Alphen et al., 2009; Kreibich et al., 2009; Smith, 1994) have stated that the important parameters affecting flood damage are mainly depth and flow velocity. In addition, if we consider the areas of greatest depths and greatest flow velocities, we can consider the Flysch as a far riskier area in terms of flash floods in individual N-year scenarios than in the Bohemian Massif. This finding is in accordance with the study of Gaal et al. (2012), where the authors examined watersheds with various geological characteristics. As noted by Norbiato et al. (2009), the influence of geology on runoff can be isolated only by comparing catchments with similar rainfall characteristics. The mean values of annual rainfall calculated for the gauged watershed in both geologically different regions from where the return period was scaled to the watershed of critical points were 979 mm in the Bohemian Massif and 1,020 mm in Flysch (4.02% difference; see Tab. 2 for details). Thus, the condition of similarity based on rainfall was fulfilled.

In this study, the dispersion in hydraulic characteristics was documented by IQR (Fig. 4). First, the three discharges (return periods) were developed at the beginning of the modelling. The dispersion was highest in Flysch watersheds. These results can be explained by the higher standard deviation of the watershed area in Flysch (Fig. 5) compared to that in the Massif. Thus, the high dispersion in IQR from the watershed area was transferred to high dispersion in IQR of discharges as they were calculated by the hydrological analogy applying the watershed area (see Equation 2). Second, the dispersion in discharges was transferred to the simulated results of hydraulic characteristics (area of inundation, water depth, flow velocity, area of depths > 1 m and flow velocity). For the area of inundation and area of depths > 1 m, the highest dispersion was found in the Flysch watersheds compared to the Massif watersheds, which agrees with the dispersion of discharges. For the water depth this was true only for scenarios Q_1 and Q_{10}. The Massif had a higher dispersion of water depth for scenario Q_{100}. Dispersion was higher in the Massif for all scenarios of flow velocity and for scenarios Q_1 and Q_{10} for areas of velocities > 1 $m.s^{-1}$ (Fig. 4). These higher values can be explained by the higher values of the standard deviation of the stream slope and higher IQR of the watershed area.

The results continue to show that during the individual peaks of the flood scenarios, the floods in the Flysch are characterised by higher magnitudes (Tab. 3). This can be explained by the reduced permeability of this geological environment, which subsequently generates a larger amount of surface runoff during floods. This is also demonstrated by Trpkosova et al. (2008), who, from a more hydrogeological point of view, examined the same geological structures with which we worked. Trpkosova et al. (2008) add that the values of the specific groundwater runoff from the Flysch area (in the Beskydy Mountains) can be up to 65% lower than for the Bohemian Massif (in the Jeseník Mountains). They further add that at the time of flood discharges, the specific groundwater runoff in the Flysch is only minimally affected compared to that of the Bohemian Massif, which corresponds to our finding of different runoff behaviours on the surface. The permeability of the geological environment itself thus seems to be an important factor in the formation of floods. This is also demonstrated by the study of Norbiato et al. (2009), where the authors additionally suggest that the analysis of hydrogeological area types can help predict flood response in ungauged watersheds. A similar topic was addressed, for example, by the studies of Chen et al. (2020) and Sharma et al. (2019), which also confirmed a certain role of the geological environment in the formation of surface runoff. In our work, we managed to further expand these findings and show that the geological environment not only affects the runoff response but also affects the hydrodynamic characteristics of floods, even in the case of flash floods. These characteristics then represent the degree of flood hazard, which is the basic input to the calculation of the flood risk itself (Merz et al., 2007; Wisner et al., 2004). Thus, it is obvious that even the resulting flood risk can be affected by different geological environments. The resulting degree of flood risk is the subject of future research.

The literature dealing with the characteristics of flash floods in connection with the geological environment is limited exclusively to karst areas. There are several studies (e.g. Bonacci et al., 2006; Gutiérrez et al., 2014; Zanon et al., 2010, etc.) that describe a specific type of flood in karst areas, which is caused by a highly permeable geological environment. There is a lack of studies dealing with specific floods in other geological areas, however. Based on the results of our work, we perceive the behaviour of floods in the geological area of the Flysch as a kind of counterpoint to karst areas. The different geology of the Flysch area of the Western Carpathians in comparison with the crystalline rocks of the Bohemian Massif, causes obvious differences in the hydrodynamic characteristics of floods; in this respect, the Flysch area and floods, which occur here with a certain specificity, add to the research.

Interesting approach and possible direction of future work would be to increase the amount of critical points applied in this study (20 in both geologic areas) to support our results. However, this extension would also cause reduced similarity of new watersheds of critical points which was defined by three watershed characteristics. In the end, this would cause increase the uncertainty in the comparison.

6. Conclusions

In this study, we focus on observations of the differences in the hydrodynamic characteristics of flash floods in geologically different areas of the Bohemian Massif (crystalline rocks) and the western Carpathians (flysch rocks). We focus our observations on the so-called critical points at which there should be a significant assumption of the occurrence of this phenomenon. In 40 analogous watersheds of critical points (20 from the Massif and 20 from the Flysch), a total of 120 2D HD models were constructed for N-year scenarios of 1-year, 10-year and 100-year flash floods. Based on the comparison of the outputs from these models, we draw the following conclusions and suggestions.

The differences in the individual hydrodynamic characteristics within the two different geological areas of the Flysch and the Massif have been clearly demonstrated. In all individual N-year scenarios, the flash floods in the Flysch zone have a larger average inundation area and a larger average depth during these inundations. Only the average flow velocities during the inundations are slightly higher in the Bohemian Massif than in the Flysch zone probably because of the higher reach slope in the Massif. If we take into account the areas with flow velocities greater than 1 $m.s^{-1}$, however, which we consider to be much riskier, then again, floods in the Flysch zone clearly prevail.

Overall, flash floods in the Flysch area appear to be riskier in all observed N-year scenarios. The geological environment can have a significant impact on the formation of flash floods and thus on the resulting flood risk. The models also show that there is not necessarily a flood risk occurrence below all critical points, even during the 100-year scenario. In addition, it is still true that in the case of the Flysch zone, the so-called endangered area is significantly larger in our study areas, which is further evidence of the greater risk from floods in this geological area.

We suggest that methodologies used for the nationwide preliminary identification of "risk points" in terms of the occurrence of flash floods should also take into consideration significant differences in geological settings in the assessed areas. These differences in the geological setting may to some extent overestimate or underestimate the above-mentioned methodologies, which may ultimately introduce uncertainties into the preliminary flood risk assessment itself.

Our work has engendered a completely new finding regarding the hydrodynamic differences of flash floods in two different geological areas. We believe that these findings will help to refine the CPM method and possibly other similar methods as an even better tool in fighting flash floods, which are increasing phenomena in Europe (Kundzewicz et al., 2014). In the future, we would like to suggest a concrete way to achieve this. Additionally, we would like to further expand this topic, specifically by studying riverine floods. We want to examine the specifics of these floods in the Flysch zone and again compare them with those in the Bohemian Massif. Subsequently, we want to assess the impact that these differences may have, for example, on flood risk assessment, various revitalisations, flood control measures or other activities that are often applied based on national methodologies, without using different approaches to different geological environments. A more comprehensive analysis of the quantified differences in flood risk values in the different areas of the Flysch and Bohemian Massif could also be very interesting.

Acknowledgements

This study was supported by the grant program of the Moravian-Silesian Region (RRC/02/2020) and by Internal grant from the University of Ostrava (SGS10/PRF/2021).

References:

ARCEMENT, G. J. (1989): Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. United States Geological Survey: Water-Supply Paper 2339.

BAKY, M. A. A., ISLAM, M., PAUL, S. (2019): Flood Hazard, Vulnerability and Risk Assessment for Different Land Use Classes Using a Flow Model. Earth Systems and Environment, 4(1): 225–244.

BATES, P. D., HORRITT, M., HERVOUET, J. M. (1998): Investigating two-dimensional, finite element predictions of floodplain inundation using fractal generated topography. Hydrological Processes, 12(8): 1257–1277.

BAUGH, C. A., BATES, P. D., SCHUMANN, G., TRIGG, M. A. (2013): SRTM vegetation removal and hydrodynamic modelling accuracy. Water Resources Research, 49(9): 5276–5289.

BERKHAHN, S., FUCHS, L., NEUWEILER, I. (2019): An ensemble neural network model for real-time prediction of urban floods. Journal of Hydrology, 575: 743–754.

BEVEN, K. J. (2009): Environmental Modelling: An Uncertain Future?. Abingdon, Routledge.

BLADÉ, E. et al. (2014): Iber: herramienta de simulación numérica del flujo en ríos. Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, 30(1): 1–10.

BLÖSCHL, G. et al. (2020): Current European flood-rich period exceptional compared with past 500 years. Nature, 583: 560–566.

BODOQUE, J. M., AMERIGO, M., DIEZ-HERRERO, A., GARCIA, J. A., CORTES, B., BALLESTEROS-CANOVAS, J. A., OLCINA, J. (2016): Improvement of resilience of urban areas by integrating social perception in flash-flood risk management. Journal of Hydrology, 541: 665–676.

BONACCI, O., LJUBENKOV, I., ROJE-BONACCI, T. (2006): Karst flash floods: an example from the Dinaric karst (Croatia). Natural Hazards and Earth System Sciences, 6(2): 195–203.

BRATH, A., MONTANARI, A., MORETTI, G. (2006): Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty). Journal of Hydrology, 324(1–4): 141–153.

BRUNNER, G. W. (2016): HEC-RES River Analysis System - User's Manual Version 5.0. US Army Corps of Engineers. Institute for Water Resources, Hydrologic Engineering Center (HEC).

BRYNDAL, T. (2015): Local flash floods in Central Europe: A case study of Poland. Norsk Geografisk Tidsskrift–Norwegian Journal of Geography, 69: 288–298.

CHEN, X., PARAJKA, J., SZÉLES, B., VALENT, P., VIGLIONE, A., BLÖSCHL, G. (2020): Impact of Climate and Geology on Event Runoff Characteristics at the Regional Scale. Water, 12(12): 3457.

CLUBB, F. J., MUDD, S. M., MILODOWSKI, D. T., VALTERS, D. A., SLATER, L. J., HURST, M. D., LIMAYE, A. B. (2017): Geomorphometric delineation of floodplains and terraces from objectively defined topographic thresholds. Earth Surface Dynamics, 5: 369–385.

ČUZK (n. d.): Digitální model reliéfu České republiky 5. generace (DMR 5G). URL: https://geoportal.cuzk.cz/(S(hg5uvv0eikuxv3c5pyise34q))/Default.aspx?mode=TextMeta&side=vyskopis&metadataID=CZ-CUZK-DMR5G-V&head_tab=sekce-02-gp&menu=302

COSTABILE, P., MACCHIONE, F., NATALE, L., PETACCIA, G. (2015): Flood mapping using LIDAR DEM. Limitations of the 1-D modelling highlighted by the 2-D approach. Natural Hazards, 77(1): 181–204.

DIAKAKIS, M., DELIGIANNAKIS, G., ANDREADAKIS, E., KATSETSIADOU, K. N., SPYROU, N. I., GOGOU M. E. (2020): How different surrounding environments influence the characteristics of flash flood-mortality: The case of the 2017 extreme flood in Mandra, Greece. Journal of Flood Risk Management, 13(3): e12613.

DIEHL, T. H. (1997): Potential Drift Accumulation at Bridges. Department of Transportation, Federal Highway Administration Research and Development, TurnerFairbank Highway Research Center, Virginia. Publication No. FHWA-RD-97-028.

DINH, Q., BALICA, S., POPESCU, I., JONOSKI, A. (2012): Climate change impact on flood hazard, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta. International Journal of River Basin Management, 10(1): 103–120.

DRBAL, K. et al. (2009): Vyhodnocení povodní v červnu a červenci 2009 na území České republiky. Metodika mapování povodňového rizika: Dílčí zpráva. Praha, VÚV TGM, Ministerstvo životního prostředí.

DUB, O. (1957): Hydrológia, hydrografia, hydrometria. Slovenské vydavateľstvo technickej literatúry.

ERNST, J., DEWALS, B. J., DETREMBLEUR, S., ARCHAMBEAU, P., ERPICUM, S., PIROTTON, M. (2010): Micro-scale flood risk analysis based on detailed 2D hydraulic modelling and high resolution geographic data. Natural Hazards, 55(2): 181–209.

EUROPEAN COMMISSION (2006): Proposal for and Directive of the European Parliament and of the Council on the assessment and management of floods. Brussels, Commission of the European Communities.

EUROPEAN COMMISSION (2007): Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. European Parliament and Council. Official Journal of the European Union, L, 288: 27–34.

FILIPOVA, V., HAMMOND, A., LEEDAL, D., LAMB, R. (2022): Prediction of flood quantiles at ungauged catchments for the contiguous USA using Artificial Neural Networks. Hydrology Research, 53(1): 107–123.

FRAGOSO, M., TRIGO, R. M., PINTO, J. G., LOPES, S., LOPES, A., ULBRICH, S., MAGRO, C. (2012): The 20th February 2010 Madeira flash-floods: synoptic analysis and extreme rainfall assessment. Natural Hazards and Earth System Sciences, 12(3): 715–730.

GAÁL, L., SZOLGAY, J., KOHNOVÁ, S., PARAJKA, J., MERZ, R., VIGLIONE, A., BLÖSCHL, G. (2012): Flood timescales: Understanding the interplay of climate and catchment processes through comparative hydrology. Water Resources Research, 48(4): W04511.

GARROTE, J., ALVARENGA, F. M., DIEZ-HERRERO, A. (2016): Quantification of flash flood economic risk using ultra-detailed stage-damage functions and 2-D hydraulic models. Journal of Hydrology, 541: 611–625.

GAUME, E. et al. (2009): A compilation of data on European flash floods. Journal of Hydrology, 367(1–2): 70–78.

GRAY, D. M. (1964): Physiographic Characteristics and the Runoff Pattern. In: Proceedings of Hydrology

Symposium No. 4 (pp. 147–164). National Research Council of Canada.

GUTIÉRREZ, F., PARISE, M., DE WAELE, J., JOURDE, H. (2014): A review on natural and human-induced geohazards and impacts in karst. Earth-Science Reviews, 138: 61–88.

GVOŽDÍKOVÁ, B., MÜLLER, M. (2017): Evaluation of extensive floods in western/Central Europe. Hydrology and Earth System Sciences, 21(7): 3715–3725.

HANZE: Historical Analysis of Natural Hazards in Europe (2017): T. U. Delft, Faculty of Civil Engineering and Geosciences, Department of Hydraulic Engineering.

HAPUARACHCHI, H. A. P., WANG, Q. J., PAGANO, T. C. (2011): A review of advances in flash flood forecasting. Hydrological Processes, 25(18): 2771–2784.

HARDY, J., GOURLEY, J. J., KIRSTETTER, P. E., HONG, Y., KONG, F., FLAMIG, Z. L. (2016): A method for probabilistic flash flood forecasting. Journal of Hydrology, 541: 480–494.

HEWLETT, J. D., HIBBERT, A. R. (1967): Factors affecting the response of small watersheds to precipitation in humid areas. Forest hydrology, 1: 275–290.

HUISMAN, J. A. et al. (2009): Assessing the impact of land use change on hydrology by ensemble modelling (LUCHEM) III: Scenario analysis. Advances in Water Resources, 32(2): 159–170.

HYDRAULIC REFERENCE MANUAL IBER V. 1.0. (2014): Two-dimensional modelling of free surface shallow water flow.

JARIHANI, A. A., CALLOW, J. N., MCVICAR, T. R., VAN NIEL, T. G., LARSEN, J. R. (2015): Satellite-derived Digital Elevation Model (DEM) selection, preparation and correction for hydrodynamic modelling in large, low-gradient and data-sparse catchments. Journal of Hydrology, (524): 489–506.

KANDILIOTI, G., MAKROPOULOS, C. (2011): Preliminary flood risk assessment: the case of Athens. Natural Hazards. 61(2): 441–468.

KREIBICH, H., BUBECK, P., VLIET, M. V., MOEL, H. D. (2015): A review of damage-reducing measures to manage fluvial flood risks in a changing climate. Mitigation and Adaptation Strategies for Global Change, 20(6): 967–989.

KREIBICH, H., PIROTH, K., SEIFERT, I., MAIWALD, H., KUNERT, U., SCHWARZ, J., MERZ, B., THIEKEN, A. H. (2009): Is flow velocity a significant parameter in flood damage modelling? Natural Hazards and Earth System Sciences, 9(5): 1679–1692.

KRZHIZHANOVSKAYA, V. V. et al. (2011): Flood early warning system: design, implementation and computational modules. In: International Conference on Computational Science: Procedia Computer Science, 4: 106–115.

KOURGIALAS, N. N., KARATZAS, G. P. (2011): Flood management and a GIS modelling method to assess flood-hazard areas—a case study. Hydrological Sciences Journal, 56(2): 212–225.

KUKAL, Z. (2005): Geologická role řek v krajině. In: KENDER, J., POŠMOURNÝ, K., KUKAL, Z. [eds.]: Krajina v geologii – geologie v krajině (pp. 45–46). Praha, Ministerstvo životního prostředí ČR.

KUNDZEWICZ, Z. W. et al. (2014): Flood risk and climate change: global and regional perspectives. Hydrological Sciences Journal, 59(1): 1–28.

KUNDZEWICZ, Z. W., PIŃSKWAR, I., BRAKENRIDGE, G. R. (2018): Changes in river flood hazard in Europe: a review. Hydrology Research, 49(2): 294–302.

LAUBER, U., KOTYLA, P., MORCHE, D., GOLDSCHEIDER, N. (2014): Hydrogeology of an Alpine rockfall aquifer system and its role in flood attenuation and maintaining baseflow. Hydrology and Earth System Sciences, 18(11): 4437–4452.

LI, W., LIN, K., ZHAO. T., LAN, T., CHEN, X., DU, H., CHEN, H. (2019): Risk assessment and sensitivity analysis of flash floods in ungauged basins using coupled hydrologic and hydrodynamic models. Journal of Hydrology, 572: 108–120.

LI, Y., WANG C. (2009): Impacts of Urbanization on Surface Runoff of the Dardenne Creek Watershed, St. Charles County, Missouri. Physical Geography, 30: 556–573.

LI, K., WU, S., DAI, E., XU, Z. (2012): Flood loss analysis and quantitative risk assessment in China. Natural Hazards, 63(2): 737–760.

LIU, L. (2018): Application of a Hydrodynamic and Water Quality Model for Inland Surface Water Systems. In: Malcangio, D. [ed.]: Applications in Water Systems Management and Modeling.

MARCHI, L., BORGA, M., PRECISO, E., GAUME, E. (2010): Characterisation of selected extreme flash floods in Europe and implications for flood risk management. Journal of Hydrology, 394(1–2): 118–133.

MOSAVI, A., OZTURK, P., CHAU, K. (2018): Flood Prediction Using Machine Learning Models: Literature Review. Water, 10(11): 1536.

MASOOD, M., TAKEUCHI, K. (2012): Assessment of flood hazard, vulnerability and risk of mid-eastern Dhaka using DEM and 1D hydrodynamic model. Natural Hazards, 61(2): 757–770.

MARK, O., WEESAKUL, S., APIRUMANEKUL, C., AROONNET, S. B., DJORDJEVIĆ, S. (2004): Potential and limitations of 1D modelling of urban flooding. Journal of Hydrology, 299(3–4): 284–299.

MERZ, B., THIEKEN, A. H., GOCHT, M. (2007): Flood risk mapping at the local scale: concepts and challenges. In: Begum, S., Stive, M. J. F, Hall, J. W. [eds.]: Flood risk management in Europe, Springer, Berlin, pp. 231–251.

MIHU-PINTILIE, A., CIMPIANU, C. I, STOLERIU, C. C., PEREZ, M. N., PAVELUC, L. E.(2019): Using High-Density LiDAR Data and 2D Streamflow Hydraulic Modeling to Improve Urban Flood Hazard Maps: A HEC-RAS Multi-Scenario Approach. Water, 11(9): 1832.

MŁYŃSKI, D. (2020): Analysis of Problems Related to the Calculation of Flood Frequency Using Rainfall-Runoff Models: A Case Study in Poland. Sustainability, 12(17): 7187.

NOVÁK, P., TOMEK, M. (2015): Prevence a zmírňování následků přívalových povodní ve vztahu k působnosti obcí: metodika. Praha, Výzkumný ústav meliorací a ochrany půdy.

NEAL, J. C., FEWTRELL, T. J., BATES, P. D., WRIGHT, N. G. (2010): A comparison of three parallelisation methods for 2D flood inundation models. Environmental Modelling & Software, 25(4): 398–411.

NTELEKOS, A. A., GEORGAKAKOS, K. P., KRAJEWSKI, W. F. (2006): On the Uncertainties of Flash Flood Guidance: Toward Probabilistic Forecasting of Flash Floods. Journal of Hydrometeorology, 7(5): 896–915.

NORBIATO, D., BORGA, M., MERZ, R., BLÖSCHL, G., CARTON, A. (2009): Controls on event runoff coefficients in the eastern Italian Alps. Journal of Hydrology, 375(3–4): 312–325.

O'CONNOR, J. E., GRANT, G. E., COSTA, J. E. (2002): The Geology and Geography of Floods. In: House, P. K., Webb, R. H., Baker, V. R. Levish, D. R. [eds.]: Ancient Floods, Modern Hazards: Principles and Applications of Paleoflood Hydrology, Volume 5. American Geophysical Union, pp. 359–385.

OPENSTREETMAP® (2019): Data file made by OpenStreetMap contributors [online] [cit. 28.08.2021]. Available at: https://planet.openstreetmap.org

PAIVA, R. C. D., BUARQUE, D. C., COLLISCHONN, W., BONNET, M. P., FRAPPART, F., CALMANT, S., MENDES, C. A. B. (2013): Large-scale hydrologic and hydrodynamic modeling of the Amazon River basin, Water Resources Research, 49(3): 1226–1243.

PAPAIOANNOU, G., LOUKAS, A., VASILIADES, L., ARONICA, G. T. (2016): Flood inundation mapping sensitivity to riverine spatial resolution and modelling approach. Natural Hazards, 83(1): 117–132.

PAPPENBERGER, F., MATGEN, P., BEVEN, K. J., HENRY, J. B., PFISTER, L., DE FRAIPONT, P. (2006): Influence of uncertain boundary conditions and model structure on flood inundation predictions. Advances in Water Resources, 29(10): 1430–1449.

PAPROTNY, D., SEBASTIAN, A., MORALES-NÁPOLES, O., JONKMAN, S. N. (2018): Trends in flood losses in Europe over the past 150 years. Nature Communications, 9(1): 1–12.

PATEL, D. P., RAMIREZ, J. A., SRIVASTAVA, P. K., BRAY, M., HAN, D. (2017): Assessment of flood inundation mapping of Surat city by coupled 1D/2D hydrodynamic modeling: a case application of the new HEC-RAS 5. Natural Hazards, , 89(1): 93–130.

PESTANA, R. et al. (2013): Calibration of 2D hydraulic inundation model in the floodplain region of the lower Tagus River. Conference paper: ESA Living Planet Symposium.

PETROSELLI, A., VOJTEK, M., VOJTEKOVÁ, J. (2019): Flood mapping in small ungauged basins: a comparison of different approaches for two case studies in Slovakia. Hydrology Research, 50(1): 379–392.

PINOS, J., TIMBE L. (2019): Performance assessment of two-dimensional hydraulic models for generation of flood inundation maps in mountain river basins. Water Science and Engineering, 12(1): 11–18.

POUSSIN, J. K., BOTZEN, W. J. W., AERTS, J. C. J. H. (2015): Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. Global Environmental Change, 31: 74–84.

RUIZ-VILLANUEVA, V., BODOQUE, J. M., DÍEZ-HERRERO, A., EGUIBAR, M. A., PARDO-IGÚZQUIZA, E. (2012): Reconstruction of a flash flood with large wood transport and its influence on hazard patterns in an ungauged mountain basin. Hydrological Processes, 27(24): 3424–3437.

RUIZ-VILLANUEVA, V., CASTELLET, E. B., DÍEZ-HERRERO, A., BODOQUE, J. M., SÁNCHEZ-JUNY, M. (2014a): Two-dimensional modelling of large wood transport during flash floods. Earth Surface Processes and Landforms, 39(4): 438–449.

RUIZ-VILLANUEVA, V., BODOQUE, J. M., DÍEZ-HERRERO, A., BLADÉ, E. (2014b): Large wood transport as significant influence on flood risk in a mountain village. Natural Hazards, 74(2): 967–987.

RUMAN, S., BALL, T., BLACK, A. R., THOMPSON, J. R. (2020): Influence of alternative representations of land use and geology on distributed hydrological modelling results: Eddleston, Scotland. Hydrological Sciences Journal, 66(3): 488–502.

RUMAN, S., TICHAVSKÝ, R., ŠILHÁN, K., GRILLAKIS, M. G. (2021): Palaeoflood discharge estimation using dendrogeomorphic methods, rainfall-runoff and hydraulic modelling-a case study from southern Crete. Natural Hazards, 105(2): 1721–1742.

SCHUBERT, J. E., SANDERS, B. F. (2012): Building treatments for urban flood inundation models and implications for predictive skill and modeling efficiency. Advances in Water Resources, 41: 49–64.

SCHUMM, S. A. (1960): The shape of alluvial channels in relation to sediment type. Washington, USGS.

SCHUMM, S. A. (1985): Patterns of Alluvial Rivers. Annual Review of Earth and Planetary Sciences, 13: 5–27.

SENE, K. (2013): Flash Floods: Forecasting and Warning. Springer.

SEYOUM, S. D., VOJINOVIC, Z., PRICE, R. K., WEESAKUL, W. (2012): Coupled 1D and Noninertia 2D Flood Inundation Model for Simulation of Urban Flooding. Journal of Hydraulic Engineering, 138(1): 23–24.

SHARMA, P. J., PATEL, P., JOTHIPRAKASH, V. (2019): Assessment of variability in runoff coefficients and their linkages with physiographic and climatic characteristics of two contrasting catchments. Journal of Water and Climate Change, 10(3): 464–483.

SMITH, D. I. (1994): Flood damage estimation – A review of urban stage-damage curves and loss functions. Water Sa, 20(3): 231–238.

SMOLDERS, S., IDES, S., PLANCKE, Y., MEIRE, P., TEMMERMAN, S. (2012): Calibrating discharges in a 2D hydrodynamic model of the Scheldt Estuary: Which parameters can be used and what is their sensitivity. In: Proceeedings of the 10th International Conference on Hydroinformatics (pp. 14–18). Hambrug, Germany.

SPELLMAN, P., GULLEY, J., MARTIN, J. B., LOUCKS, J. (2019): The role of antecedent groundwater heads in controlling transient aquifer storage and flood peak attenuation in karst watersheds. Earth Surface Processes and Landforms, 44(1): 77–87.

SRINIVAS, K., WERNER, M., WRIGHT, N. (2009): Comparing forecast skill of inundation models of differing complexity: the case of Upton upon Severn. London, Taylor & Francis Group.

ŠTĚPÁNKOVÁ, P., DUMBROVSKÝ, M., DRBAL, K. (2017): The Assessment of Level of Flash Floods Threat of Urbanised Areas. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 65(2): 519–526.

SUBRAMANYA, K. (2008): Engineering Hydrology. 3rd edition. New Dehli, Tata McGraw-Hill Publishing Company Ltd.

TENG, J., JAKEMAN, A. J., VAZE, J., CROKE, B. F. W., DUTTA, D., KIM, S. (2017): Flood inundation modelling: A review of methods, recent advances and uncertainty analysis. Environmental Modelling & Software, 90: 201–216.

TRPKOSOVA, D., KRASNY, J., PAVLIKOVA, D. (2008): Differences in runoff conditions of crystalline and flysh regions in Moravia and Silesia. Journal of Hydrology and Hydromechanics, 56(3): 201–210.

UNDRR (2019): Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland, United Nations Office for Disaster Risk Reduction.

VAN ALPHEN, J., MARTINI, F., LOAT, R., SLOMP, R., PASSCHIER, R. (2009): Flood risk mapping in Europe, experiences and best practices. Journal of Flood Risk Management, 2(4): 285–292.

VAZE, J., TENG, J., SPENCER, G. (2010): Impact of DEM accuracy and resolution on topographic indices. Environmental Modelling & Software, 25(10): 1086–1098.

VINCENDON, B., DUCROCQ, V., NUISSIER, O., VIÉ, B. (2011): Perturbation of convection-permitting NWP forecasts for flash-flood ensemble forecasting. Natural Hazards and Earth System Sciences, 11(5): 1529–1544.

VOJTEK, M., PETROSELLI, A., VOJTEKOVÁ, J., ASGHARINIA, S. (2019): Flood inundation mapping in small and ungauged basins: sensitivity analysis using the EBA4SUB and HEC-RAS modeling approach. Hydrology Research, 50(4): 1002–1019.

VOJTEK, M., VOJTEKOVÁ, J. (2016): Flood hazard and flood risk assessment at the local spatial scale: a case study. Geomatics, Natural Hazards and Risk, 7(6): 1973–1992.

WANG, Y., LI, Z., TANG, Z., ZENG, G. (2011): A GIS-Based Spatial Multi-Criteria Approach for Flood Risk Assessment in the Dongting Lake Region, Hunan, Central China. Water Resources Management, 25(13): 3465–3484.

WINSEMIUS, H. C. et al. (2016): Global drivers of future river flood risk. Nature Climate Change, 6(4): 381–385.

WISNER, B., BLAIKIE, P., CANNON, T., DAVIS, I. (2004): At Risk: Natural Hazards, People's Vulnerability and Disasters. Routledge.

XIA, X., LIANG, Q., MING, X. (2019): A full-scale fluvial flood modelling framework based on a high-performance integrated hydrodynamic modelling system (HiPIMS). Advances in Water Resources, 132: 103392.

ZANCHETTA, A. D. L., COULIBALY, P. (2020): Recent Advances in Real-Time Pluvial Flash Flood Forecasting. Water, 12(2): 1–29.

ZANON, F. et al. (2010): Hydrological analysis of a flash flood across a climatic and geologic gradient: The September 18, 2007 event in Western Slovenia. Journal of Hydrology, 394(1–2): 182–197.

ZELEŇÁKOVÁ, M., GAŇOVÁ, L., PURCZ, P., SATRAPA, L. (2015): Methodology of flood risk assessment from flash floods based on hazard and vulnerability of the river basin. Natural Hazards, 79(3): 2055–2071.

Please cite this article as:

SPÁLOVSKÝ, V., RUMAN, S., TRIZNA, M. (2022): A comparison of the hydrodynamic characteristics of surface runoff generated by flash floods in geologically different areas of the Bohemian Massif (crystalline rocks) and the western Carpathians (flysch). Moravian Geographical Reports, 30(2): 134–148. doi: https://doi.org/10.2478/mgr-2022-0009

Fig. 10: International train Czeremcha (PL) – Vysokolitovsk (BY) at Czeremcha station in 2011 (Photo: K. Kowalczyk)

Fig. 11: Ukrainian sleeping coach of Kyiv–Berlin international train at Kyiv station in 2011 (Photo: K. Kowalczyk)

Illustrations related to the paper by T. Komornicki et al.