THE IMPACT OF ROAD TRANSPORTATION NETWORKS ON THE TERRITORIAL DISTRIBUTION OF POPULATION AND SETTLEMENTS. CASE STUDY: NORTH-WEST DEVELOPMENT REGION OF ROMANIA.

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ABSTRACT

This study examines the impact of road transportation networks on the territorial distribution of population and settlements in the North-West Development Region of Romania from 1992 to 2021. Focusing on six counties: Cluj, Sălaj, Bihor, Satu Mare, Maramureș, and Bistrița-Năsăud, the research uses the Pearson correlation coefficient to analyze the relationship between Road network Density (RDI) and Population and Settlements distribution (PSI) over four census years (1992, 2002, 2011, 2021). RDI, widely used metric in transportation planning, urban development, and environmental studies, measures road density by considering the length and category of roads (European, National and County Road) for each road type in each county. PSI, an original metric introduced in this study, combines data on the population of each locality with its rank based on governmental classification and is calculated for every European, National, and County Road in each county. The analysis reveals a significant correlation between the road network of higher importance (measured by road category) and population distribution in the territory. Thus, the more important the road is, the more population it attracts. Urban and suburban areas, particularly those with enhanced road connectivity, have experienced population growth, while more isolated rural regions have faced declines due to demographic changes and migration.

Key-words: *Road density index; Population and settlements index; Locality population; Locality rank; Pearson correlation coefficient.*

1. INTRODUCTION

Transportation plays a crucial role in shaping geographic and socio-economic landscapes. Since the Industrial Revolution, the development of transportation systems, marked by innovations as the steam engine, locomotive, and automobile, has dramatically transformed human mobility and settlement patterns. These advancements have revolutionized the movement of people and goods, profoundly affecting land use, urban development, and population distribution (Krylov, 2020). The provision of better transport infrastructure has not only increased the speed and range of travel, but has also altered the population's access to various services and opportunities (Vickerman, 1994; Hansen, 1959). Furthermore, it is considered to provide better access to the locations of input materials, and lead to markets that are more productive and competitive (Hasan, Wang, Khoo, & Foliente, 2017). The location of modern economic activities is less and less dependent on local natural resources and is primarily oriented along the best-organized transport axes, towards consumption centers, and regions with a less demanding workforce (Muntele & Ungureanu, 2017).

Historically, transportation infrastructure has influenced the spatial organization of cities and regions. The establishment of railways and highways facilitated the expansion of urban areas, connected previously isolated regions (Li, Zhang, & Yang, 2024), and stimulated economic growth by linking markets and resources. This connectivity fosters economic opportunities, influences real estate values, and impacts the distribution of populations (Muñoz, Soza-Parra, & Raveau, 2020).

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According to Central Place Theory, road networks serve as key determinants of settlement patterns by providing access to economic opportunities, healthcare, education, and other essential services (Ajaelu, Bemsodi, Eke, & Giwa, 2024). As transportation networks evolve, they continue to shape the geographic distribution of people and businesses (Cervero, 2003), often leading to shifts in settlement patterns and mobility, which affects travel from residency to the location of facility (Dadashpoora & Rostami, 2017). Therefore, transportation network became the fundamental critical infrastructure for the movement of people and good (Nagurney, 2011; Reggiani, Nijkamp, & Lanzi, 2015).

The relationship between transportation infrastructure and population dynamics is a critical area of study. Enhanced transportation conditions generally increase the attractiveness of regions for residents and businesses (Lakhminarayanan, Nair, & Chandrasekar, 2024), leading to higher population concentrations and more dynamic urban growth. For example, improvements in road networks and public transit systems can make certain areas more accessible (Wang, Han, & de Vries, 2019) and desirable, influencing demographic trends. Transportation systems act as catalysts for urban growth and decline (Rodrigue, 2020), affecting how settlements expand and how they integrate into larger regional frameworks.

The impact of transportation infrastructure extends beyond immediate urban areas to broader regional and national scales. Improved transportation networks can shift economic and population flows (Perl & Goetz, 2014), affecting land use patterns, regional development, and also economic disparities. Moreover, factors such as natural conditions, economic opportunities, urbanization levels or tourism elements interact with transportation infrastructure in order to shape population distribution. Understanding these interactions is essential for planning and enforcing policy making (Nachtigall, Krbalkova, Cap, Hermankova, & Vojtek, 2024), as it helps to identify how to optimize transportation improvements to achieve balanced regional development.

In this context, the current study focuses on how the road transportation networks influence the territorial distribution of population and settlements, with a specific analysis on the North-West Development Region of Romania from 1992 to 2021. This region provides a convincing case study due to its diverse landscape and varying levels of infrastructure development over time. Road infrastructure is particularly significant, as it can accelerate population movements, considering other factors as well (Guangqing, 2012; Duranton & Turner, 2012), and according to Brandily and Rauch (2024), cities with greater road density and road evenness in the center have shown faster population growth, emphasizing the role of well-developed road networks in fostering urban expansion and connectivity. For each county in the North-West Development Region of Romania (Cluj, Sălaj, Bihor, Satu Mare, Maramureș, Bistrița-Năsăud), various indicators at the locality level have been calculated for the census years of 1992, 2002, 2011, and 2021. These indicators were analyzed using Pearson correlation to interpret the data.

For a better and deepen understanding of the relationship between road infrastructure and settlement patterns, alternative methodological approaches already used in the specialized literature can also be considered. One such method involves the use of Geographic Information Systems (GIS) combined with spatial analysis techniques. This approach, widely recognized in the literature, allows for a detailed spatial and temporal analysis, incorporating data collection on road networks and settlements, GIS mapping, and advanced spatial analysis techniques such as hotspot analysis, spatial autocorrelation, and spatial regression (Xie & Levinson, 2011). Additionally, the application of agent-based modeling (ABM) (Sun, Axhausen, Lee, & Huang, 2013) has emerged as another alternative method for examining the interaction between transportation infrastructure and population dynamics. ABM allows for the simulation of individual behaviors and interactions within a virtual environment, providing insights into how changes in road infrastructure might influence population movements and settlement decisions over time. These methods, alongside qualitative approaches like interviews and case studies, offer a comprehensive understanding of the relationship between road infrastructure and population distribution.

Therefore, the study aims to elucidate the interconnected nature of road transportation and settlement dynamics by examining how the development of road networks influences population distribution and settlement patterns. This objective can be solved either with the help of GIS (Nicoara P.-S. & Haidu, 2014), sometimes including a GEODATABASE (Nicoara M.E. & Haidu, 2011; Nistor & Nicula, 2021) or by using social and spatial statistical techniques (Xie & Levinson, 2011; Ji et al., 2014). The research hypothesis suggests that roads of higher significance, categorized as European, National, or County level, tend to attract greater population concentrations, indicating a bidirectional relationship between infrastructure development and population distribution.

2.MATERIALS AND METHODS

This research was conducted along two main directions: the analysis of the road transportation network of the region and the distribution of the population in relation to this network. Each component of the study was analyzed using specific indicators. The values obtained for each road were compared with the values from the population analysis, and the data were interpreted using the Pearson correlation coefficient, which measures the strength and direction between two numerically expressed variables.

The database of population by localities for the four census years (1992, 2002, 2011, and 2021) and the calculation of indicators were done using Microsoft Office Excel. The resulting values were then transferred to the Social Science Statistics platform to calculate the Pearson correlation coefficient. For each European, National, and County Road, the two indicators below were calculated. In total, over 300 roads and more than 1000 localities were considered in this research. Hence, this study focused on each county in the region, however the communale roads were excluded as they primarily serve to connect neighboring localities part of the same administrative-territorial unit and do not play a significant role at the county level.

2.1.Transportation Network

The first indicator is RDI (Road Density Index), which is calculated for each road described above and it is determined by the following formula, as defined by Ji et al., 2014:

$$RDI = \frac{k \times l}{S} \tag{1}$$

where:

k= the coefficient based on the type of road (European road = 4, National Road = 3, County Road = 2, Communal Road = 1);
l= the length of the road (km);
S=area of the unit.

The original formula calculates road density based on the total length of roads, weighted by road type, and the unit area. In the original study, roads were classified as expressways (k=5), national roads and second, third, and fourth ring roads (k=4), municipal roads (k=3), first-grade urban roads (k=2), and county and other roads (k=1), based on the metropolitan area of Beijing. However, in our study the coefficients (k) were modified to reflect the classification of roads in Romania. Therefore, roads were classified under administrative grading as being European roads, National roads, County roads and Communale roads. For the purposes of this study, we set the weight of a European as 4, the weight of National as 3, County roads as 2 and Communale roads as 1. As we already mentioned before, the communale roads have not been taken in consideration. Unlike Ji et al.'s study, where the unit area was the metropolitan area of Beijing, in this study, the unit area corresponds to the area of each of the six counties of the region, as the analysis is conducted individually for each county.

2.2. Population and Settlements

The second indicator, concerning population and settlements (PSI), presents a more complex calculation method, reflecting the originality of the study. While the RDI is calculated based on a formula already used in the literature, the following formula is a new proposal derived from analyzing quantitative data on population and settlements.

$$PSI = \frac{\sum_{i=1}^{n} Pl_i \times \sum_{i=1}^{n} k_i}{n} \tag{2}$$

where:

Pli= the population of the locality traversed by the road (which will be expressed in relative values);
ki= coefficient of the locality related to its rank;
n= number of localities.

We will start by exemplifying how this formula is constructed, focusing initially on the first variable, *Pli.* For better understanding, in the traversal from i=1 to n, all localities crossed by the respective road are recorded. Thus, for each road, the population volume is calculated by summing the absolute values of the inhabitants of each locality traversed. The absolute population of each locality along the road was summed, and this total was then expressed as a percentage of the county's stable population recorded in each census (1992, 2002, 2011, and 2021). This percentage-based approach was chosen due to significant fluctuations in the county's population over the three decades. Furthermore, since the study focuses on the distribution of the population within the territory, analyzing relative values provides a better understanding and perception of the actual state of affairs. In this context, we will take as example Sălaj county. 2000 inhabitants represented in 1992 0.75%, in 2002 the same value of 2000 was 0.81%, while in 2011 0.89%. By analyzing these relative values, it is clearly visible that the same number of inhabitants has a different significance.

The second variable, *ki* represents a coefficient assigned to each locality based on the rank established by Romanian Government Law No. 351 (2001), which highlights the Section IV of the National Spatial Planning Plan (**Table 1**). Assigning a coefficient equal to the rank would have expressed an inverse proportionality since localities with a higher number of inhabitants would have received a lower score compared to localities with a much smaller population. To avoid this, we used a scoring system that mirrors the rank. In other words, the table below illustrates the bonus system used. To briefly illustrate the identification of *ki*, all coefficients of the localities traversed by the analyzed road are summed up in the end. Finally, after multiplying the two variables discussed earlier (*Pli* and *ki*), the result is divided by the number of localities crossed by that road.

Table 1.

Coefficient assigned for each locality based on rank.

Rank	Locality	Coefficient assigned
0	The capital of Romania, a municipality of European importance (Bucharest)	6 (N/A for this study)
I	Municipalities of national importance, with potential influence at the European level (Cluj-Napoca, Oradea)	5
II	Municipalities of inter-county, county-level importance, or with a balancing role in the network of localities. (Satu Mare, Zalău, Dej, etc.)	4
III	Towns (ex. Huedin, Șimleu Silvaniei, Jibou, Tășnad, etc.)	3
IV	Villages that are commune centers (e.g., all commune centers)	2
V	Villages that are components of communes and villages belonging to municipalities and towns	1

As a methodological note, several situations were identified where a locality is traversed by multiple roads. Thus, the locality was assigned to the road of higher category/importance (European, National and County). As an example, if a locality is crossed by both a County road and a National road, it is assigned to the National road, as it belongs to a higher category. However, it is important to mention that there were no cases where a road of a lower category had a greater length than a higher-category road within the same locality. A second particular case occurs when two roads of the same category traverse a locality. In this case, the locality was assigned to the road that covers a longer distance within the settlement.

Additionally, since the variables' values have changed significantly over the years, particularly *Pli*, the PSI value for each analyzed road was calculated for the years 1992, 2002, 2011 and 2021. Thus, four values were calculated for each road. The map below (**Fig. 1**) illustrates the road network based on category and the classification of settlements by rank.

Fig. 1. Roads by category and localities by rank of the North-West region of Romania.

2.3. Pearson correlation coefficient

The values obtained for each road through RDI and PSI (for 1992, 2002, 2011, and 2021) were translated using Pearson's coefficient, which serves to highlight the level of correlation between these two indicators.

To calculate the correlation level of the indicators for the four censuses, we used the Pearson's correlation formula, and for a simpler and easier notation, we applied the following variable substitution: RDI = X and PSI = Y.

$$r = \frac{SP}{\sqrt{SS_X \times SS_Y}} \tag{3}$$

where:

$SP = (X - x)(Y - y)$, *where x= average values of the variable X and y= average values of the variable Y;*
$SS_X = (X - x)^2$;
$SS_Y = (Y - y)^2$.

In this study, the Pearson correlation coefficient has the goal to assess the relationship between RDI and the PSI. It is important to clarify that Pearson measures the strength and direction of the correlation between these two variables but does not directly establish causality. The aim of our analysis was to explore the level of correlation between RDI and PSI, with a particular focus on understanding how the road network (RDI) relates to the distribution of population and settlements (PSI).

However, while Pearson correlation does not imply causation, the theoretical framework of the study posits that the road network influences the distribution of population and settlements. This hypothesis is supported by the structure of the two indices. The RDI, which is based solely on road-related variables (such as road length and category), reflects the road transport itself, and thus can be considered the "cause" in this context. On the other hand, the PSI expresses the road network but related to population and settlements, effectively representing the "effect" of road infrastructure on demographic and settlement patterns. Thus, while our analysis measures the correlation between RDI and PSI, the conceptual framework behind the study supports the idea that improved road infrastructure, as captured by the RDI, leads to changes in population distribution and settlement patterns, as reflected by the PSI. This reasoning aligns with the existing literature, which demonstrates that better-connected areas attract more population due to improved accessibility to economic, educational, and healthcare opportunities (Rodrigue, 2020).

3. RESULTS

The detailed analysis of demographic changes in the North-West region of Romania reveals a notable shift in population distribution, strongly correlated with improvements in road infrastructure. Over the period from 1992 to 2021, while absolute population numbers have decreased significantly in many localities, the relative values of population distribution within each county provide a clearer picture of these shifts.

In most counties there has been a marked decline in population in more isolated and rural areas (**Fig. 2**). This decline is primarily attributed to demographic aging and migration trends, where individuals from these rural regions have moved either to urban centers within Romania or to other countries in search of better economic opportunities, healthcare, and educational services.

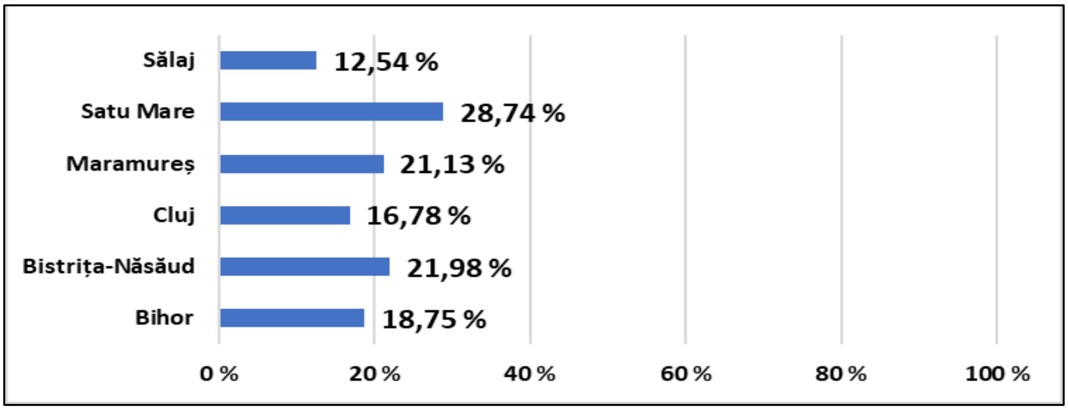

Fig. 2. The percentage of rural localities in each county that recorded population increases between 1992 and 2021.

The graphic presents the percentage of rural localities that recorded population increases between 1992 and 2021. These results indicate that, while some rural areas have seen population growth, the overall trend suggests a general decline in population across most rural localities.

As road infrastructure improved, urban and suburban areas, such as those in Cluj and Bihor, have seen relative increases in population. These (sub)urban centers have become more attractive due to enhanced connectivity, job opportunities, and overall living conditions, leading to a redistribution of the population from less accessible rural areas. Thus, while the total population in many localities has decreased, the relative distribution of population within the counties shows a concentration around areas with better road category and connectivity. This reflects the importance of analyzing relative population values to understand the impact of infrastructure on demographic changes and the broader trend of urbanization and migration.

According to Evans (1996), the obtained values fall into the moderate and high categories, generally showing an upward trend. It is worth nothing that for 2021, all values are categorized as high. Below (**Table 2** and **Fig. 3**) it is shown the correlation coefficient for each county during period of time analyzed.

Table 2.

The results of Pearson correlation coefficient for each county between 1992-2021.

County	1992	2002	2011	2021
Bihor	0,590	0,652	0,680	0,718
Bistrița-Năsăud	0,580	0,584	0,615	0,637
Cluj	0,648	0,653	0,720	0,755
Maramureș	0,513	0,507	0,568	0,614
Satu Mare	0,672	0,659	0,697	0,730
Sălaj	0,650	0,680	0,710	0,726

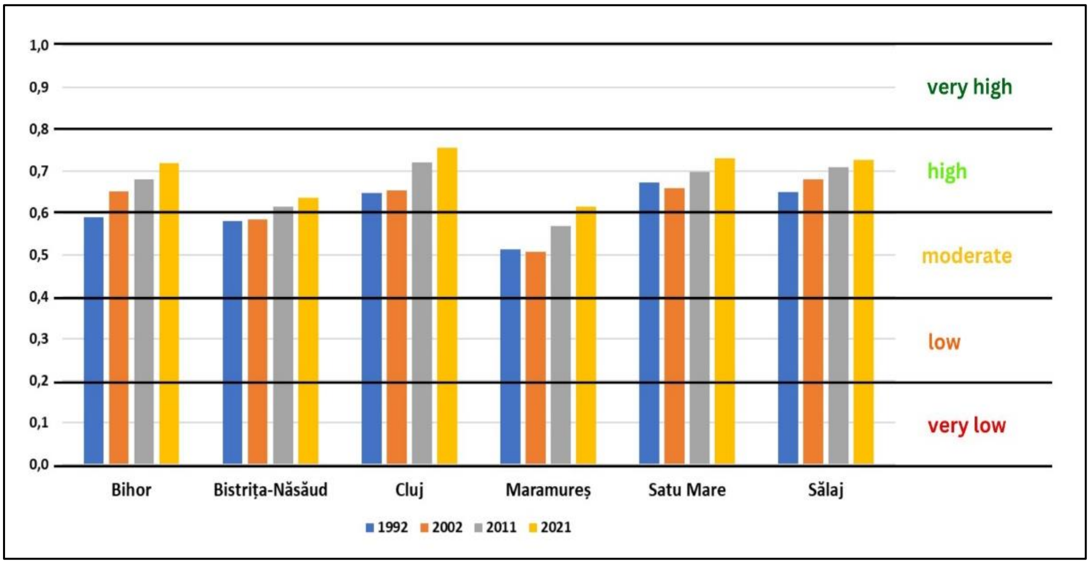

Fig. 3. Evolution of Pearson correlation coefficient.

4. DISCUSSIONS

The Pearson correlation coefficient shows a consistent increase across the six counties analyzed. This trend highlights the growing influence of road infrastructure on population dynamics, with urban centers and well-connected areas attracting growth, while isolated rural settlements face demographic decline. Interpretation and discussion of the results are carried out in qualitative terms, but their deduction was carried out through procedures that fall within the specific branch of technical geography (Haidu, 2016).

In Bihor County, the correlation coefficient between the density of the road network and the population distribution increased from 0.590 in 1992 to 0.718 in 2021. This growth reflects the development of road infrastructure and the migration of the population towards better connected areas with more economic opportunities. Regarding the road infrastructure, major European roads of significant importance, such as E60, E79, and E671, all converge in Oradea, the primary polarizing center of the county (Tălângă, 2015). These high category roads attract population growth not only to Oradea but also to other key urban localities within the county, including Salonta, Aleșd, Beiuș, and Ștei. Notably, among the top six most populous settlements in the county, Marghita is the only town not traversed by a European road. Instead, it is served by National Road 19B. However, with the completion of A3 highway, Marghita will be located less than 5 km from this major infrastructure, potentially enhancing its connectivity and appeal.

Oradea has become a major attraction, drawing residents from nearby communes. Localities such as Sânmartin and Borș, both served by E79, have experienced population growth due to the proximity, accessibility and economic development. For instance, in 1992, Sânmartin's population was 1.18% of Bihor County's total, but by 2021, it had increased to 2.26%, nearly doubling. This growth can be attributed to the migration of people and families (especially from Oradea to suburban of Sânmartin) attracted by the urban amenities and job opportunities available in Oradea and Sânmartin, with direct access to the European road E60. In contrast, more isolated villages from South-East such as Pietroasa or Uileacu de Beiuș have seen significant population declines, reflecting the lack of access to important road infrastructure and limited by mountains.

In Bistrița-Năsăud County, the correlation increased from 0.580 in 1992 to 0.637 in 2021, indicating a territorial redistribution of the population in favor of higher category roads. Bistrița, the county's most important city, is traversed by European road E58. Towns such as Beclean and Sângeorz-Băi, located along European and National roads, have benefited from this improved road access, recording population increases.

For example, Beclean, traversed by the European road E58, has seen population growth, from 3,55% of Bistrița County's total in 1992 to 3,80% in 2021, due to transport facilities that have improved access to jobs and services. In contrast, smaller and more isolated villages have experienced significant population declines due to the aging population and migration.

The Pearson correlation values in Bistrița-Năsăud do not indicate as significant increases compared to other counties. Specifically, population fluctuations in the urban area are not as pronounced as in Bihor, for example. Although a pattern of polarization around Bistrița is observed, these results are significantly influenced by the general population decline and demographic aging.

Cluj County has shown a significant increase in the correlation coefficient, from 0.648 in 1992 to 0.755 in 2021. Cluj-Napoca, an important university and economic center, is traversed by E60, leading to increased population attraction. Suburban localities such as Florești and Apahida have recorded significant demographic increases due to their proximity to Cluj-Napoca and improved road access. On the other hand, in the suburban area of Cluj-Napoca there are more examples of population increment, such as Gilău, Feleacu, Baciu, Jucu de Sus, Chinteni, etc.

Florești has become one of the fastest localities in Romania when talking about growing, benefiting from its proximity to Cluj-Napoca and easy access to the European road E60. The growth in job opportunities in the IT sector and technology parks has attracted a younger and skilled workforce. Just to realize that in 1992 Florești had around 6.000 inhabitants (0,83% of Cluj County) and in 2021 the population is more than 50.000 people (7,76%). Technically, Cluj-Napoca and Florești are two different settlements, however are effectively sticked to each other, so in different contexts Florești becomes attached to Cluj-Napoca.

While Florești is located to the west of Cluj-Napoca, the east exit of the city is marked by Apahida, which shows also significant progress, but not as Florești, from 1,04% in 1992, to 2,54% in 2021.

Cluj-Napoca is a very important university center of Transylvania and even of Romania, so every year a massive number of students come to the city and suburban area (Florești, Apahida, Baciu, etc.). However, there is not an official number of how many students are actually leaving around the city, since their home address is not actually Cluj-Napoca, but for sure the number of inhabitants is bigger than the actual census.

On the other hand, in general villages have seen population declines due to demographic aging, migration and limited access to infrastructure and services. In this context, in the last three decades there are more than 5 villages which ended up with 0 inhabitants.

To conclude, a specific factor for Cluj has been the intense development of the real estate sector in suburban areas, attracting numerous young families. Additionally, access to higher education institutions and a dynamic business environment has contributed to attracting and retaining young professionals in Cluj-Napoca and surrounding localities. Most of the villages have not benefited from these advantages and have suffered due to demographic aging and population migration to urban and suburban areas. Thus, in analyzing relative values, increases are evident in areas close to Cluj-Napoca, compared to significant declines in more isolated localities.

In Maramureș County, the correlation increased from 0.513 in 1992 to 0.614 in 2021. Baia Mare, the county capital, traversed by European road E58, has become a polarizing center if we take in consideration also the settlements around (Tăuții-Măgherăuș, Săsar, etc.). Analyzing Baia Mare just by itself, reveals a constant population decrease of over 40,000 people in 30 years, which leads to a relative decline of more than 3% at the county level.

Between 1992 and 2002, the correlation level between road network density and population distribution slightly decreased at the county level. This decline can be attributed to the massive migrations of the local population to Western Europe in search of better job opportunities. This phenomenon is particularly specific to Maramureș, where many individuals, especially young people, left their home regions to pursue employment abroad. As a result, significant demographic shifts occurred, leading to a temporary decrease in the correlation values. Many rural and less accessible areas experienced heightened depopulation due to this large-scale migration.

Borșa is a relatively small polarizing center, located over 120 km from Baia Mare, a distance that grants it this polarizing status, and also considering the mountain between them, which becomes a barrier. National Road 18, the most important road in the area, enhances Borșa's accessibility and attractiveness. These two attributes have contributed to Borșa's population increase, taking in consideration also the tourism. In contrast, many nearby localities, such as the isolated village of Budești, have not benefited from the same economic opportunities and have suffered from significant depopulation. The low accessibility of these villages has further exacerbated population declines. Additionally, the emigration of young people to Western Europe for seasonal work has had a significant impact on local demographics, leaving many rural communities with an aging population. Although the absolute population of the polarizing centers has not increased significantly, the analysis of relative values shows a more concentrated distribution around these centers.

In Satu Mare County, the Pearson correlation coefficient increased from 0.672 in 1992 to 0.730 in 2021. This trend indicates a stronger relationship between road infrastructure and population distribution over time. Satu Mare, the county capital, is traversed by European road E81 and E671, making it a central point that has attracted residents in suburban areas from surrounding rural areas. Localities such as Păulești and Mărtinești define the suburban area, marked by massive population growth. For example, Mărtinești had approximately 200 people in 1992, and now it has 1200, while Păulești grew from 780 to nearly 2000.

Between 1992 and 2002, the correlation level between road network density and population distribution in Satu Mare County slightly decreased, primarily due to massive migrations to Western

Europe in search of better job opportunities. This phenomenon was particularly pronounced in the Negrești-Oaș area, where many individuals, especially young people, migrated abroad in the early 2000s. These significant demographic shifts led to a temporary decrease in the correlation values, with many rural and less accessible areas experiencing significant depopulation.

Migration trends in Satu Mare are influenced by its proximity to the border with Hungary, facilitating easier access to Western European countries. Many young people have migrated to these countries for better employment prospects, leaving rural areas with an aging population and further exacerbating local demographic decline. Despite these challenges, urban and suburban areas connected by European and National roads have shown relative population growth, underscoring the importance of road infrastructure in shaping demographic patterns.

In Sălaj County, based on the results obtained, we can affirm that there is a strong correlation between the calculated indices, namely RDI and PSI, over the years 1992-2021. Generally, these values indicate a uniform distribution of the population under the influence of road transport infrastructure. In this context, the importance of roads, categorized at the European, National, or County level, plays a significant role in the population distribution within Sălaj County.

The increase in the correlation coefficient from 0.650 in 1992 to 0.726 in 2021 suggests an improvement in road infrastructure and a redistribution of the population. Zalău, the polarizing center of the county, is traversed by the E81, the main road axis of the county, connecting the northwest to the southeast with Satu Mare and Cluj. Along the E81, many localities have experienced significant percentage growth in terms of population distribution, including Românași, Hereclean, and Badon. This indicates a strong relationship between road infrastructure and population distribution, highlighting the importance of the E81 in facilitating regional connectivity and development.

As previously mentioned, the correlation index has intensified for the four analyzed moments. Thus, the population tends to move towards settlements closer to urban areas, either within the county seat, Zalău, or in the suburban area, with the best examples being Aghireș and Crișeni. Proximity to urban centers offers high accessibility and adapts to the needs of citizens, including the educational, healthcare, financial sectors, and job opportunities. For instance, Crișeni, bordering Zalău, has grown from just over 2000 inhabitants in 1992 to over 3300 in the latest census.

On the other hand, the evolution of the correlation must also be analyzed at the level of rural localities outside the suburban area, which are facing demographic aging and population decline. Therefore, more young people are choosing to leave their villages in favor of the favorable conditions and opportunities offered by urban areas (Li, Westlund, & Liu, 2019) or migrating to more economically developed countries. Additionally, at the county level, there are multiple settlements that exist "only on paper" as they have become abandoned in reality, with no inhabitants recorded in the 2021 census. The most notable examples are the localities of Țărmure and Pădureni, which have disappeared in reality.

Thus, the relative distribution of the population shows increases in better connected areas and an evident decline in more isolated localities.

5. CONCLUSION

The study aimed to demonstrate a correlation between the road transportation network and the territorial distribution of population and settlements in the North-West Development Region of Romania from 1992 to 2021, and roads of higher significance, categorized as European, National, or County level, tend to attract greater population concentrations. However, this analysis cannot be strictly limited to the road network and population distribution alone. Other factors such as access to education, healthcare, and job opportunities also play significant roles. Without any doubt, our study would have been enhanced if economic data at the locality level were available. Unfortunately, such data exists only at the regional or county level. Therefore, this is why we included only data on road length and category, population, and rank of localities in the RDI and PSI formulas.

The analysis indicates a clear trend of population concentration around areas with higher category road. The Pearson correlation coefficients for each county demonstrate a consistent increase when comparing 1992 to 2021, underscoring the significant role that road networks play in shaping demographic trends. Most correlation values fall into the strong correlation category: 0.6-0.8. Although Maramureș and Satu Mare experienced a slight decrease in the early 2000s, caused by massive migration to the Western Europe, all counties exhibited an overall upward trend.

On the other hand, the findings highlight a marked urbanization trend, with significant population growth in suburban areas, particularly those with enhanced road connectivity. Cluj-Napoca and its surrounding localities, such as Florești and Apahida, experienced substantial demographic increases due to their proximity to major roads like the E60 and the presence of economic opportunities. This trend is consistent across other counties, where urban centers attract populations from rural areas, facilitated by better road infrastructure.

In contrast, the study reveals a decline in population in more isolated and rural areas. Factors such as demographic aging, migration, and limited access to infrastructure and services have contributed to this decline. The relative population values show a concentration around better-connected areas, while more remote villages experience significant depopulation. At the regional level, 11 localities have been identified that, over the course of 30 years, have reached a population of 0 and have effectively disappeared.

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