

Article

Sustainable Development of Transport as a Regional Policy Target for Sustainable Development—A Case Study of Poland

Marek Ogryzek  and Ada Wolny-Kucińska * 

Institute of Land Management and Geography, Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, 10-719 Olsztyn, Poland; marek.ogryzek@uwm.edu.pl

* Correspondence: ada.wolny@uwm.edu.pl

Abstract: In central and eastern European countries that joined the European Union (EU) in 2004 and 2007, there are strong connections between transport development and sustainable regional development. The needs for transport development in post-socialist countries are so high that it is difficult to finance them, and most governments have to choose between immediate and less urgent needs. The aim of this study was to determine the role played by sustainable transport growth in the improvement of regional cohesion and sustainable regional development with a use of geographical information systems' capabilities. The specific goals of the study were to: (i) determine the impact of EU subsidies on the regional transport development; (ii) identify threats to regional cohesion resulting from under-capitalised regions, (iii) examine geographical information systems' capabilities in periodical regional transport development monitoring. The analyses include evaluation of the regions' involvement in sustainable transport development as well as the presentation of direct and indirect results, such as road system improvement, with the use of GIS capabilities. It is particularly important to develop a system for monitoring the level of EU fund allocation with the use of GIS tools and the capabilities of geographic information systems. Such in-depth analysis would be useful for regional governments and decision-makers in creating and updating long term transport policies as well as monitoring long term regional development strategies. Both sustainable transport development and EU fund allocation can be monitored within the use of GIS tools, and such analyses should supplement the INSPIRE Geoportal scope.

Keywords: road network; sustainable development; transport policy; EU funds; INSPIRE Geoportal



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1. Introduction

Regional cohesion and sustainable regional development are pivotal components of development strategies in the European Union countries, especially those which acceded to the community following transformations of their political systems, with their legacy as centrally controlled post-socialist countries. In central and eastern European countries that joined the EU in 2004 and 2007, there are strong connections between transport development and sustainable regional development. This has been described by researchers from Hungary [1], the Slovak Republic [2,3], Romania [4] and Lithuania [5].

According to the World Commission on Environment and Development [6], people should be able to make development sustainable in order to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Intergenerational equity lies at the core of sustainability. Countries are improving their road network systems because, in meeting the UN Sustainable Development Goals (SDGs), they are influencing the achievement of an adequate level of development. The resolution adopted by the General Assembly on 25 September 2015 for sustainable development adopted 17 Sustainable Development Goals and 169 related targets [7]. The topic of sustainable transport is included in particular in the following goals: 9 (Industry, innovation and infrastructure), 11 (Sustainable cities and communities), and 17 (Partnership for the goals).

Every transport system on earth plays a major role in the sustainability of our planet. Moreover, transport systems themselves must be sustained in order to continue providing all people access to the economic and social opportunities necessary for leading a meaningful life [8]. The question as to how transport capacity and transport improvement influence the economies of societies with both underdeveloped and developed road networks has long been debated. As we review previous studies made for different NUTS (Nomenclature of Territorial Units for statistics in European Union) classification levels, we may find accessibility to be an important sustainable development determinant for provinces, agglomerations and cities [9,10]. Furthermore, some regional and international authorities have paid particular attention to this subject, because transport development has become an essential stimulant of regional development in the EU, especially in the post-socialist countries. The EU funds are of key importance for this development; therefore, the study will show how they are used in the Polish regions and how this translates into the growth of road networks since Poland's accession to the EU. Regional sustainable development indicators and visualisation of results were conducted in the GIS environment. Sustainable transport using GIS has been used by many scientists [11–20]. To visualise the results, cartographic presentation methods generating cartograms and cartodiagrams are used [21–25].

According to previous studies, accessibility is defined as the ease with which 'goods can reach other places', measured in terms of time, cost, seasonality, and transport services provided [26]. The accessibility is an important factor for European regional cohesion. The relationship between transport infrastructure and regional cohesion has played a key role in the policies and actions of the European Commission related to the Trans-European Transport Networks [27]. The main goal is to serve the totality of the European continent, effectively reducing the cost of transport between the various regions of the union [28]. As for transport services, the ease with which a destination can be reached is said to be low where transport services are poor in terms of departure choice, number of operators, modal choice, regularity, and affordability [29].

The EU policy strategies have generated a huge demand for research to build a better understanding of the linkages between transport investment and accessibility on the one hand, and the potential of accessibility to achieve regional policy goals on the other [28]. An efficient and reliable transport system is the backbone of the development of any national or regional economy [30]. While many policies and plans are focused on optimising traffic, in practice this can counteract environmental protection measures. Achievement of both goals would require integration between the two fields. However, infrastructure policy and planning in particular were strongly sectoral in nature, leading to fragmented policy actions and the development of their own goals, along with the aim to implement these irrespective of potentially conflicting ambitions formulated in other policy sectors [31]. One of the most popular policies is transit-oriented development (TOD), a policy area that encompasses both land-use and transport planning [32,33]. An integrated planning approach to transport development has been implemented, which presumes a comprehensive view in which 'all related aspects of mobility are considered and conflicts and complementarities among the various policy fields are taken into account, rather than the implementation of single, sector-bound policy measures' [31].

The White Paper on transport issued in 2011 [34] needs to be taken into account in any consideration of the EU transport policy. The aims of a sustainable transport system identified in this document are: (a) creating a unified transport area; (b) achieving a competitive and resource efficient transport system; (c) developing rail and multimodal transport; (d) the need for infrastructure planning that will minimise the degrading impact on the environment; and (e) the use of modern technology and innovative traffic and information management as the key to reduction of fuel emissions.

Road improvement (as well as the betterment of other means of transport) leads to direct effects in the form of reduced journey time, reduced costs and improved reliability [29]. The benefits from these effects will be passed on to future road users, passengers

and companies. Changes to patterns of accessibility may lead to the emergence of network effects, whereby some sites may receive additional benefit owing to their advantageous location [35] with respect to a road network. It is further anticipated that these will lead to beneficial effects for the communities affected by a given road.

However, Greek researchers suggest that the EU cohesion policy, which aims to improve spatial accessibility and to reduce regional inequalities by means of a transport-oriented plan, might accelerate the process of industrial concentration towards the core and more developed regions instead of creating equal opportunities for less developed regions [36]. Improvements in transport networks may also represent powerful growth stimuli only at specific moments, but have limited effects in other time periods [37].

The European Commission considers transport as a pillar of development [36]. According to the White Paper [34] of 2011, setting a framework for safe, sustainable transport and innovative mobility are essential for European citizens. This goal should be considered at the national, regional and lower levels when creating transport policies.

At the national level, for example, the Polish Transport Policy for 2006–2025 [38] was published in Poland in 2005. It seems that the national instrument is premature in relation to the White Paper, but an analysis of their content indicates that both documents are quite consistent. Polish Transport Policy indicates detail objectives for transport development in our country [38], such as: (a) improvement of transport accessibility and quality of transport as a factor for improved living conditions and removal of development barriers; (b) support to the competitiveness of the Polish economy as a key instrument for economic development; (c) improvement of the efficiency of the transport system; (d) integration of the transport system by branches and in the territorial system; (e) improvement of road traffic safety; and (f) reduction of the negative impact of transport on the environment and living conditions.

These requirements were taken into consideration in regional policies—regional development strategies. Although they do not form separate transport policies, they take into account the priorities of the transport development in these documents. An analysis of these strategies manifests the importance of transport development, as it was one of the strategic or operational objectives and, in some cases, a development priority [39–54]. It should be emphasised that a vast majority of these strategies were adopted after the White Paper and the Polish Transport Policy were issued. The article presents the priorities and main trends in the development of transport, together with the accomplishment of individual tasks.

This study attempts to answer the following key questions: (i) Do Polish regional authorities make enough effort to develop sustainable transport? (ii) What measures are taken? Are they effective? Do they meet the needs of regional communities? And finally, (iii) Can they be analysed and monitored periodically with the use of geographical information systems and capabilities of GIS tools? Therefore, the aim of this study is to determine the role played by sustainable transport growth in the improvement of regional cohesion and sustainable regional development with a use of GIS tools and geographical information systems' capabilities. The specific goals of the study were to: (i) determine the impact of EU subsidies on the regional transport development; (ii) identify threats to regional cohesion resulting from undercapitalised regions; and (iii) examine GIS tools and geographical information systems' capabilities in periodical regional transport development monitoring.

The remainder of the paper is organised as follows. Section 2 describes the materials and methods, including the characteristics of the research area and the use of GIS capabilities. The main principles of our approach, as well as the used sources and methods, are explained in Section 2.1. In Section 3, the results of the detailed analyses are presented to be subsequently discussed in Section 4. Finally, Section 5 concludes the paper and outlines further work.

2. Material and Methods

2.1. Methodology and Data Sources

As the analysis of the literature has shown, the accessibility of regions and their internal cohesion remain important issues. This is particularly seen in the countries of Central and Eastern Europe, which made the development of infrastructure a priority after the 1990s political transformation and subsequent access to the European Union, while maintaining it as one of the main stimulants of their socioeconomic growth. Several investment projects were carried out in these countries, especially with regard to expressway networks. What followed was better road accessibility, mainly in major Polish cities and agglomerations, which are among the principal beneficiaries of the programmes (ring roads, connection via a network of motorways and expressways). However, Polish roads with high technical standards are still in short supply (motorways and expressways) [55], and improvement in this area is highly recommended.

Grants from the European Regional Development Fund (ERDF) and Cohesion Fund (CF) support the poorest European regions so as to narrow the development gap and achieve higher economic and social cohesion among the EU states. Transport development, as a key goal of the regional development in all Polish provinces, translates into the use of EU funds for this purpose. This is why the expenditures on transport development in the financial perspective 2007–2013 are taken into consideration. Investment projects accepted for financing in the financial perspective 2007–2013 were implemented up until 2015. For the purpose of this study, the list of beneficiaries of the Polish Operational Program Infrastructure and Environment (OPIandE) was analysed [55]. However, only the expenditures on transport development were selected.

Moreover, there is another Operational Program supported by EU funds in the financial perspective 2007–2013, called the Operational Program for Development of Eastern Poland (OPDEP), and its range of influence was limited to the area of five provinces: Lubelskie (LU), Podlaskie (PD), Podkarpackie (PK), Świętokrzyskie (SW) and Warmińsko-Mazurskie (WM). This program was an additional element of support from the Structural Funds to implement projects of key importance for socio-economic development in these regions [56]. Among the priorities of this operational program, there are four that refer to transport development: (a) national road development with the emphasis on construction of bypasses on key national roads, (b) regional and local roads network improvement, (c) construction of cycle paths, and (d) urban transport development.

The scale of this analysis consists of the NUTS 2 level units, which in Poland are identified as provinces. Therefore, the research was conducted on the basis of statistical data, documents, and specialised material collected for the 16 Polish provinces, where the state of transport infrastructure and conditions for its development are varied. The analyses were adjusted to the level of data availability and borders of the selected units. For the purpose of the comparison, certain GIS capabilities are essential. That is why both universal methods for implementation and the level of spatial analyses will be shown. The study followed the stages illustrated in Figure 1.

2.2. Study Area

The study area consists of 16 Polish provinces (NUTS 2 units). These are regions with populations between almost 1 million people and 5.5 million people. According to Central Statistical Office (CSO) data [56], the average population is about 2.4 million people. Since the EU accession in 2004, 7 of 16 experienced depopulation, with the largest decrease in Śląskie (SL): –183,136. However, Śląskie (SL) is the most densely populated Polish province, with 366 inhabitants per km² (Figure 2). On the other hand, there are provinces that noted a noticeable population growth of over 100,000 people [56]. The highest population growth (277,171) belongs to Mazowieckie (MZ), which has the second place in terms of population density (225 people per km²). Still, a few provinces have population densities five or even six times lower than Śląskie (SL) (Figure 2).

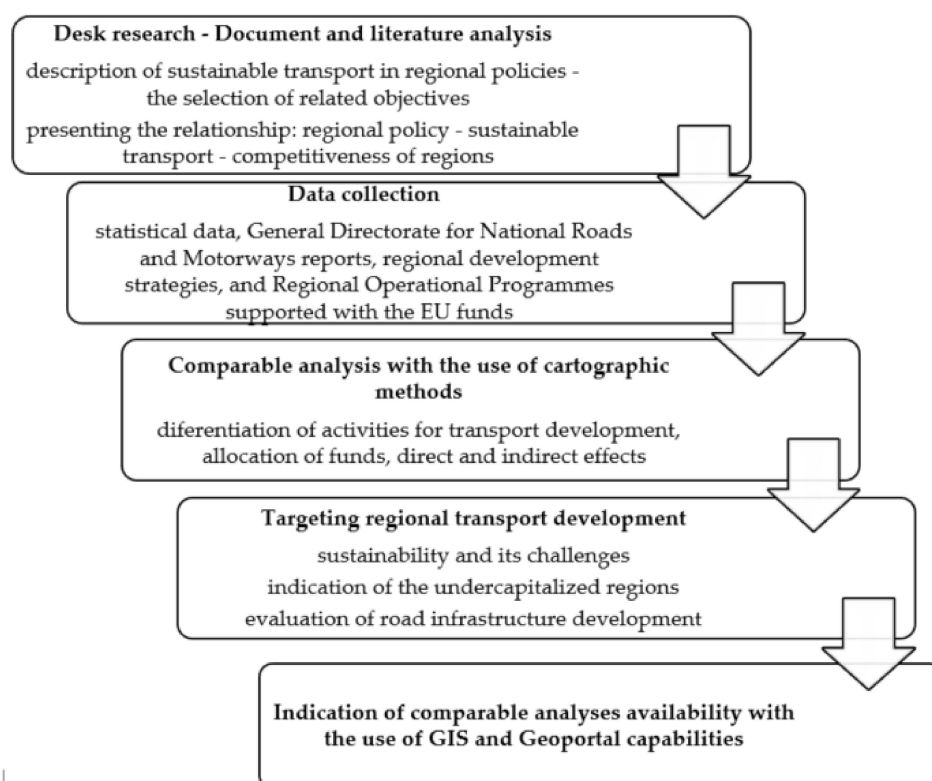


Figure 1. The research procedure.

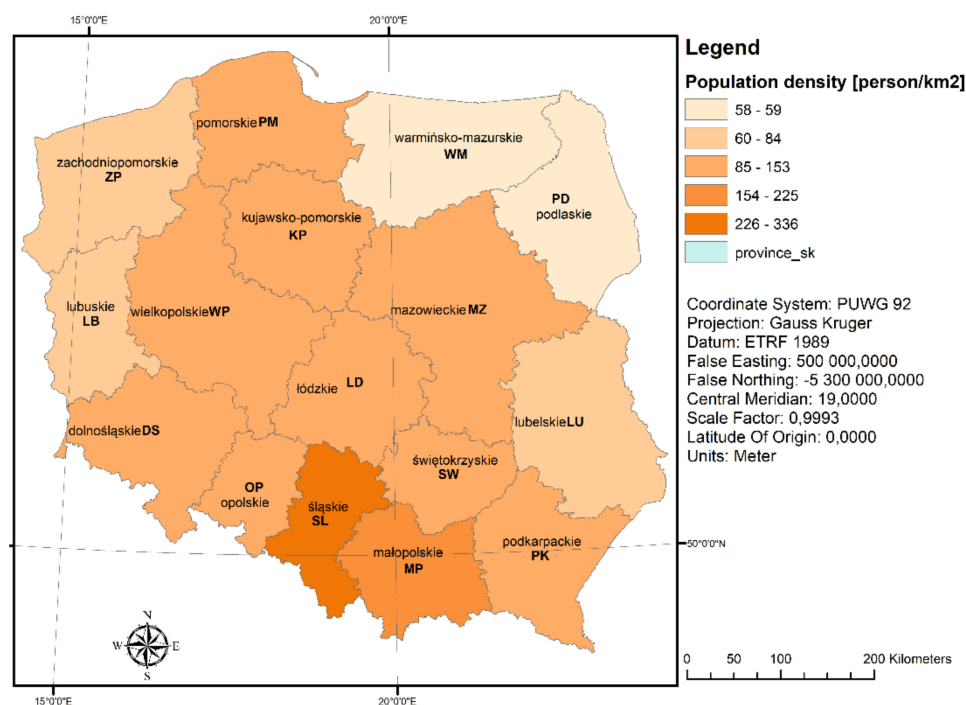


Figure 2. The study area with population density. Source: the authors, based on [56].

After EU accession in 2004, Polish provinces were the area of large transport investments, with a special emphasis on road network improvement. Polish national and regional authorities implemented numerous road infrastructure projects, with major investments in express road networks. These resulted in the increase of statistical measures reported at

the level of Polish provinces, such as length of public roads per 100 km² (except Opolskie) and the length of express roads and motorways per 100 km² (Table 1). The network of expressways and motorways was the most developed in Łódzkie and Śląskie (Table 1). However, the largest growth in public roads length per 100 km² does not correspond with the indicator for express roads and motorways. Other means of transport were neither as developed as the road network, nor were the results as significant. In particular, the indicators for rail transport are not satisfying—there is a decrease in railway length per 100 km² and stagnation in the electrification of railway lines (Table 1). Moreover, the data availability does not cover the entire period—for example, the length of cycle paths (where first data were reported in 2011)—but the increase is significant and promising.

Table 1. Characteristics of transport development. Source: the authors based on [56].

Province	The Increase in Indicator Values				
	Length of Public Roads per 100 km ² (2004–2019)	Length of Express Roads and Motorways per 100 km ² (2004–2019)	Railway Length per 100 km ² (2004–2019)	Electrified Railway Length in km (2004–2019)	Cycle Path Length per 100 km ² (2011–2019)
Dolnośląskie (DS)	9.8	1.38	−0.3	32	2.53
Kujawsko-Pomorskie (KP)	19.6	1.13	0.0	1	3.73
Lubelskie (LU)	30.5	0.52	−0.2	113	2.63
Lubuskie (LB)	19.1	1.71	−0.6	4	2.73
Łódzkie (LD)	12.9	2.37	−0.2	34	3.19
Małopolskie (MP)	23.2	0.78	−0.3	−38	2.92
Mazowieckie (MZ)	17.4	1.05	0.0	−37	4.46
Opolskie (OP)	−8.7	0.00	−0.5	−44	2.76
Podkarpackie (PK)	18.1	1.02	0.0	37	2.56
Podlaskie (PD)	37.4	0.51	0.4	−1	2.23
Pomorskie (PM)	15.9	0.71	−0.7	5	4.65
Śląskie (SL)	1.3	1.85	−1.6	−122	3.95
Świętokrzyskie (SW)	11.2	0.70	0.2	5	1.94
Warmińsko-Mazurskie (WM)	2.3	0.99	−0.3	2	1.74
Wielkopolskie (WP)	5.4	1.06	−0.9	0	4.25
Zachodniopomorskie (ZP)	6.0	1.06	0.1	10	2.20

2.3. Methods of Calculation and Tools for Analysis

Although there are different measures of technical infrastructure development (with a focus on road investments), such as the Hellwig's measures of development [57], the road density scoring methods suggested in [3], measures of economic efficiency of road and bridge projects [58], the analytic network process (ANP) for evaluating sustainable transport policies [59], the Logistics Performance Index (LPI) with emphasis on quality of transport infrastructure and information technology [60], or theil indexes for transport demand [61], the authors decided to use indicators tailored to the needs of this study.

This step may lead to the identification of provinces that are undercapitalised, unsustainable, and threatened by exclusion (caused by the decreased accessibility), or even show if the involvement was disproportionate to the needs of the region in the area of road network development.

To make comparable analyses more transparent, we selected the data and created indicators showing the involvement of regions in sustainable transport development. The first one is based on the number of activities described in regional development strategies that address different means of transport, including the range and scale of the activity (Equation (1)).

$$I_i = \frac{a_i * w_i}{\sum_{i=1}^n a} \quad (1)$$

where:

li —partial indicator for the specified means and type of transport

$w(i)$ —weight of activities $w_{(1)} = 0$, $w_{(2)} = 0.25$, $w_{(3)} = 0.50$, $w_{(4)} = 0.75$, $w_{(5)} = 1.0$ (weights depend on the appearance of activities in the strategy, their importance for the province and their spatial impact on the whole province or just its parts—towns, cities, municipalities, etc.)

$w(1)$ —lack of activities in the strategy

$w(2)$ —marginal range of the activity

$w(3)$ —activities are concentrated in a part of province or they are too general

$w(4)$ —provincial range of the activity, there are areas that are not affected by the activity

$w(5)$ —national range of the activity or whole province (with detailed localities) was concerned

ai —number of activities in a regional development strategy according to different means of transport

$a1$ —number of activities for expansion of road routes of national importance

$a2$ —number of activities for expansion of road routes of regional importance

$a3$ —number of activities for construction of ring roads

$a4$ —number of activities for modernisation and renovation of railways

$a5$ —number of activities for urban and suburban transport development

$a6$ —number of activities for air transport development

$a7$ —number of activities for inland waterways development

$a8$ —number of activities for multimodal and cargo transport development

Indicators of the involvement in the development of road transport (I_1 , I_2 , I_3), water and air transport (I_6 , I_7) were grouped and supplied by the indicators for cargo and integrated transport, railways, public urban and suburban transport. Consequently, five standardised indicators were created.

The use of EU funds has played a key role in the development of road transport in Poland [62]. That is why the impact of this source of funding cannot be omitted. Hence, the absorption indicator was used, which calculates the level of EU funding [63]. This allowed us to determine the impact of the analysed activity in each of the provinces (or municipalities) (Equation (2)).

$$Ia = \frac{f}{a} * 100 \quad (2)$$

where:

Ia —absorption indicator

f —total amount of EU funds used for transport development in a province in Polish zlotys (PLN)

a —area of the province in km^2

Furthermore, we used one of the indicators published by the General Directorate for National Roads and Motorways in their annual reports. It is known as the indicator of immediate repair needs ($Irni$) in provinces, where ‘immediate needs’ concern road sections in bad condition (class D on a four-step scale) [64]. This factor is calculated as the ratio of the length of a road in bad state of repair to the length of the road in a given province (Equation (3)).

$$Irni = \frac{l_{Di}}{l_{Ti}} \quad (3)$$

where:

$Irni$ —indicator of immediate repair needs in a province

l_{Di} —length of national roads in bad state (class D) in km

l_{Ti} —length of national roads in the province in km

Raw data in the form of databases were imported into the GIS environment. Then, the raw data obtained from the databases of the General Directorate for National Roads and Motorways and Expenditures on transport development in provinces from the Operational Programme were processed according to the method of sustainable transport indicators developed by the authors; more precisely, the measures of sustainable transport growth

were applied. The GIS technology was used for both the estimation of the indicators and visualisation of the research results. The key to connecting the databases and the attribute table of the province layer was the territory number (TERYT). Territory is a unique number—not a repeating sequence of numbers identifying Polish provinces, communes and counties. The ‘join table’ function allows spatial visualisation of the collected data and its analysis, processing and re-visualisation of the results. Unified data enabled us to present accurately the information and to highlight the differences between the selected cartographic methods [65].

The diversification of expenditures on transport development was visualised in a cartodiagram, where the relationship between spatial variability and intensity of variability can be indicated [66]. The cartogram and cartodiagram methods were applied for the visualisation of changes observed in transport infrastructure, as cartograms are used to display the relative data and cartodiagrams present the spatial distribution of absolute phenomena. To emphasise a change in the intensity of a given phenomenon, different shades (from light to dark) are used [67]. The maps were made in GIS software using ArcMap. For symbolisation, graduated colours in Natural Breaks classification were used, where the data in each case are divided into five classes. Natural Breaks classes are based on natural groupings inherent in the data. Class breaks are identified with the best group similar values that maximise the differences between classes. The variables are divided into classes whose boundaries are set at relatively big differences in the values of the data. Natural Breaks are data-specific classifications and are not useful for comparing multiple maps built from different underlying information. This classification is based on the Jenks’ Natural Breaks algorithm [68–70].

The value of a single road transport development evaluation was determined with a vector analysis of the value of training grounds. Then, all the values obtained were normalised to five classes of the Jenks’ Natural Breaks algorithm. In the next step, the median value of the road transport development evaluation was determined on the basis of standardised R1–R5. In this paper, the authors also performed a raster analysis, where the raw data values from the road transport development evaluation were converted into values in the raster output target size 2500. The Feature to Raster tool was used for this purpose (Conversion). Then, the output data of the rasters were reclassified to a scale of five degrees using the Reclassify (Spatial Analyst) tool.

In the next step, the raster algebra was made using the Raster Calculator (Spatial Analyst) tool. This tool builds and executes a single Map Algebra expression using the Python syntax in a calculator-like interface. The Raster Calculator tool generally follows the standard connectivity behaviour of models in the Model Builder, with some exceptions resulting from the requirements to formulate a valid Map Algebra expression [21]. The Map Algebra is often used for area selection—determining (typing) areas which meet some conditions or determining areas which do not meet the criteria (excluded areas)—widely used in geography, crisis management, spatial planning, transportation and environmental protection. The result of adding rasters was reclassified to five classes using the Reclassify (Spatial Analyst) tool.

In the last step, we compared the result of the raster and vector analysis. In this paper, both raster and vector analysis was done, but outside of GIS, raster analysis would be practically infeasible. Even though attribute base analysis is obtainable in statistical environments, GIS was used to provide spatial data.

Additionally, the research was supplemented by basic descriptive statistics in order to standardise and compare data acquired from reports, web publications and other sources of information.

3. Results

The comparison includes the total value of the implemented transport development project standardised with the use of NUTS 2 units (provinces) and denoted as the indicator of absorption in the map (Figure 3). Additionally, the percentages of expenditures

on different priority subjects were visualised with the cartodiagram method (Figure 3). These priority subjects were classified into five groups: seaports and waterways, airports, multimodal transport and intelligent transport systems, railways, and national roads and motorways.

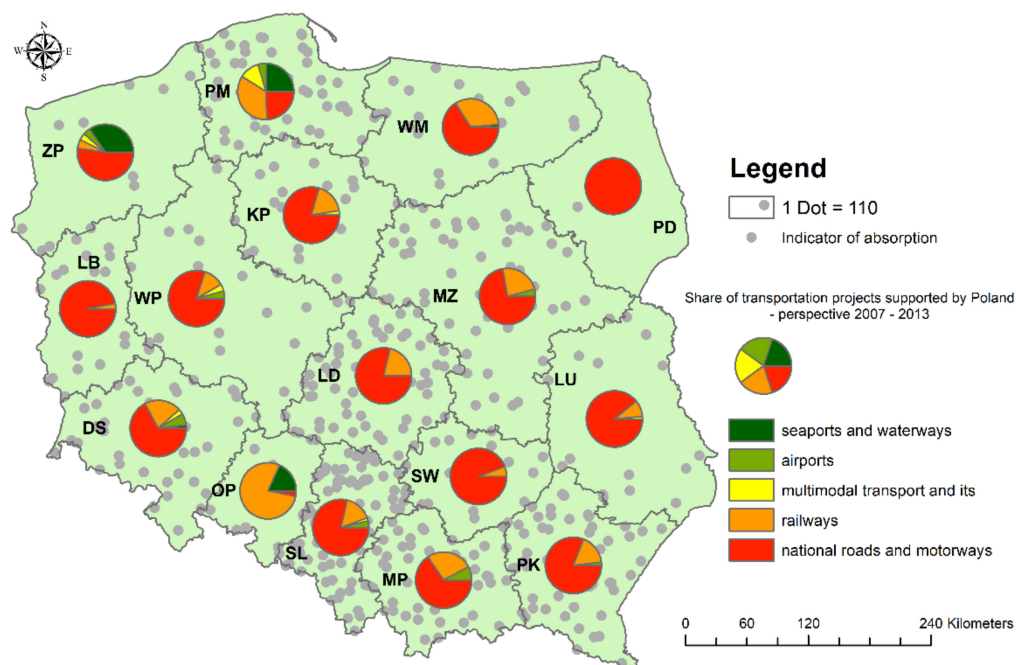


Figure 3. Expenditures on transport development in provinces with a use of Operational Program Infrastructure and Environment implemented in the financial perspective 2007–2013. Source: the authors, based on [62].

The absorption indicator shows the diversification of total expenditures on transport development in the provinces in relation to their area. As shown in Figure 3, two provinces in the south (Łódzkie (LD) and Śląskie (SL)) spent the most (more than 615,000 PLN/km²). These are the provinces where there are three of the most important transport corridors (A1 and A2 motorways in Łódzkie (LD), and also the A1 and A4 motorways in Śląskie (SL)), which have boosted the growth of a local road grid and affected the total amounts spent.

The most underinvested five provinces are Podlaskie (PD), Świętokrzyskie (SW) and Lubelskie (LU), Opolskie (OP), Zachodniopomorskie (ZP), with less than 200,000 PLN/km². They lie in different parts of the country, so the location of a province or its area did not affect the results. Among these provinces, it was only Opolskie (OP) that chose to spend these limited funds on railways rather than roads.

However, the significance of priorities differs when we consider the share of transport projects calculated in absolute values (Figure 3). Thus, 14 out of 16 provinces invested the most in road network development. The share of investments in roads and motorways even exceeded 90% in Podlaskie (PD), Świętokrzyskie (SW) and Lubuskie (LB). Only Pomorskie (PM) and Opolskie (OP) used funds for railway improvement in the first place. Air and multimodal transport does not seem to have more than a 12% share in total investments, and water transport appears to have a significant role, mostly on the seaside in the north of Poland (Zachodniopomorskie (ZP) and Pomorskie (PM)).

Moreover, funds from the Operational Program for Development of Eastern Poland (OPDEP) are compared in Table 2.

Table 2. Expenditures on transport development in provinces from the Operational Program for Development of Eastern Poland implemented in the financial perspective 2007–2013. Source: the authors.

Province	Total Value of All Projects in the Financial Perspective 2007–2013 (Operational Program for Development of Eastern Poland) [in THOUS. PLN]					Expenses on Transport per km ²
	National Roads	Regional and Local Roads	Cycle Paths	Urban Transport	Total	
Podlaskie (PD)	960,190.5	234,123.3	41,254.8	352,603.6	1,588,172.2	78.7
Kujawsko- Pomorskie (KP)						
Pomorskie (PM)						
Śląskie (SL)						
Świętokrzyskie (SW)	230,131.7	360,901.1	25,096.1	341,568.1	957,697	81.8
Małopolskie (MP)						
Lubelskie (LU)	272,408.7	931,958.8	54,099.0	505,715.9	1,764,182.4	70.3
Łódzkie (LD)						
Warmińsko- Mazurskie (WM)	442,392.9	-	85,237.0	650,136.1	1,177,766	48.7
Opolskie (OP)						
Wielkopolskie (WP)						
Podkarpackie (PK)	820,451.5	516,335.3	73,260.7	521,579.1	1,931,626.6	108.2
Zachodniopomorskie (ZP)						
Mazowieckie (MZ)						
Dolnośląskie (DS)						
Lubuskie (LB)						

The Podlaskie (PD) province implemented transport development projects supported by the OPDEP for a total amount of 1,588,172.2 thous. PLN (78.7 thous. PLN/km²), with a 75% share of road network development projects. The Warmińsko-Mazurskie (WM) province did not use these funds for regional and local road network improvement, which reduced the share of road investments to 38% and meant more focus on urban transport development (55% of investments supported by OPDEP). The value of projects per km² appears to be the lowest (48.7 thous. PLN/km²). The share of road network development projects in three other provinces is similar (between 60% and 70%). However, the absorption of funds differs: Świętokrzyskie (SW) allocated 81,7845 PLN/km² and Lubelskie (LU) 70.2 thous PLN/km² to transport development, while Podkarpackie (PK) was the only province which spent over 100 thous. PLN/km². Table 2 shows the direct results of the implementation of the Operational Program for Development for Eastern Poland in terms of regional transport development.

It should be emphasised that road network improvement seems to be a priority type of investment funded by the Polish Operational Programs for Infrastructure and Environment and subsidised from the EU funds. One of the objectives of our analysis of the involvement of the provinces in transport development has been to determine whether this direction in development is still being pursued.

The commitment of the Polish provinces to transport development is one of the sets research problems, and was investigated by calculating values of the indicators for each province according to data acquired from regional development strategies. The indicators allowed us to standardise information describing the mentioned involvement. Figure 4 presents the results developed using the cartodiagram method, where each bar in the chart represents involvement in the development of a different means of transport: roads, urban and suburban transport, waterways and air transport, railways, cargo and multimodal transport.

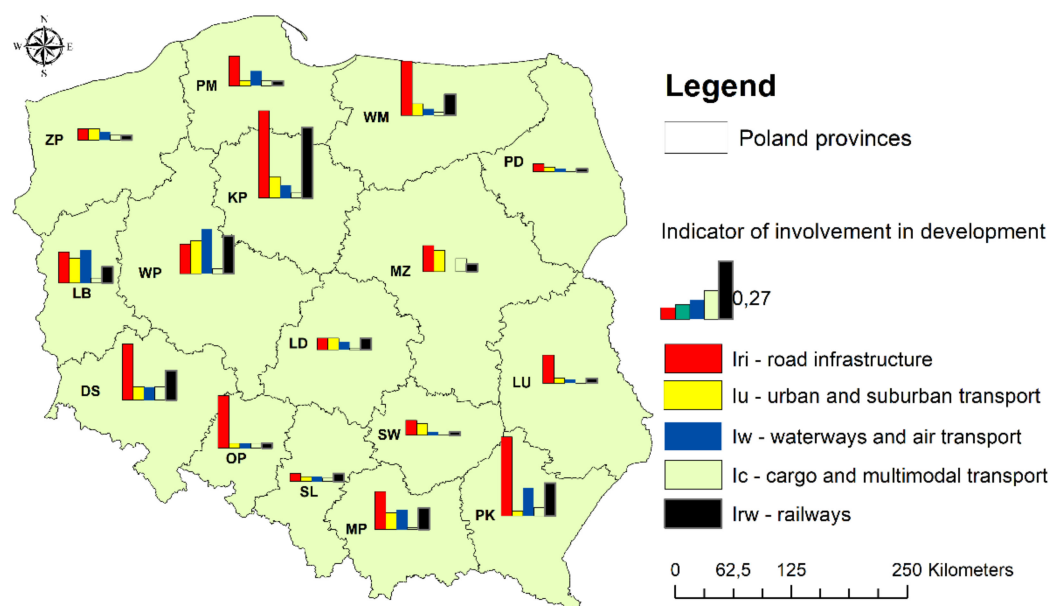


Figure 4. Involvement of the provinces in transport development—a comparison of the indicators of involvement. Source: the authors.

Values of the indicators in the range (0.1) were calculated with an accuracy of two decimal places. High values of the indicator related to the development of road infrastructure were observed in almost every province, but in two (Podkarpackie (PK) and Kujawsko-Pomorskie (KP)) it reached 0.5. It was only in Wielkopolskie (WP) that this means of transport was not considered as the one that needed the greatest involvement, but the values for all means of transport in this province are approximately the same. The situation is similar in Łódzkie (LD), where three indicators have equal values (Figure 4). Moreover, the values for the provinces differ, which might also be a consequence of less detailed description of activities or highlighting only chosen investments.

It is noticeable that the development of the road network in the Polish provinces is the highest priority that every regional government would like to achieve, because the indicator of involvement in road infrastructure is the highest partial indicator in every province (Figure 4). Therefore, the next stage of our analysis concentrated on this transport sector. To identify the state of road network development, the reports on changes in the condition of roads were investigated.

In Poland, motorways and state roads are classified based on their technical condition. The reports on changes in the condition of roads are published by the General Directorate for National Roads and Motorways (GdNRM). Our comparison involved three reports published by the General Directorate for National Roads and Motorways (GdNRM) in 2004, 2015 and 2018. The selection of these reports is not random. The first one was published in the year Poland joined the EU. The second was published after the completion of the investments from the financial perspective 2007–2013. The last one includes changes made five years after the financial perspective 2014–2020, and is the most current one.

The above reports have different descriptions of four road condition scores (A, B, C, and D, where D is the worst condition). Scores A (good condition) and B (acceptable condition) have a common description [64]. These classes are described in Figure 5, which takes into account changes in descriptions among the years.

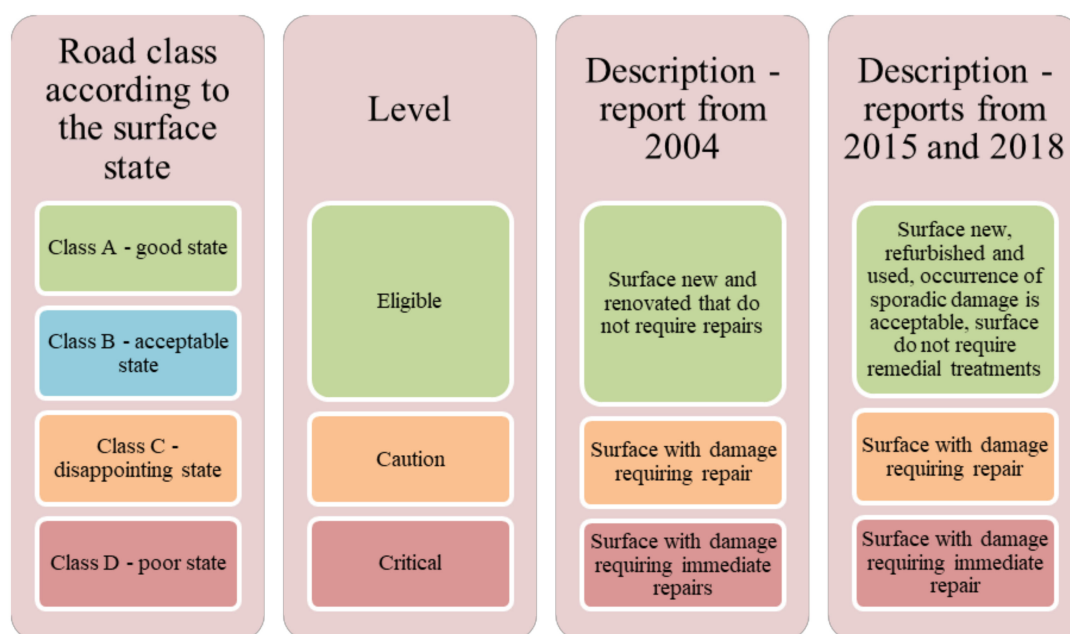


Figure 5. Road classification based on their technical condition Source: the authors, based on [64].

Among the indicators considered, the indicator of immediate repair needs (Irn) in the provinces was assessed, where ‘immediate needs’ concern road sections in bad condition (class D) [64]. According to data referring to the state of roads in the Polish provinces compared with the use of cartographic methods, Figure 6 presents a comparison of Irn acquired from the three mentioned reports (from 2004, 2015 and 2018).

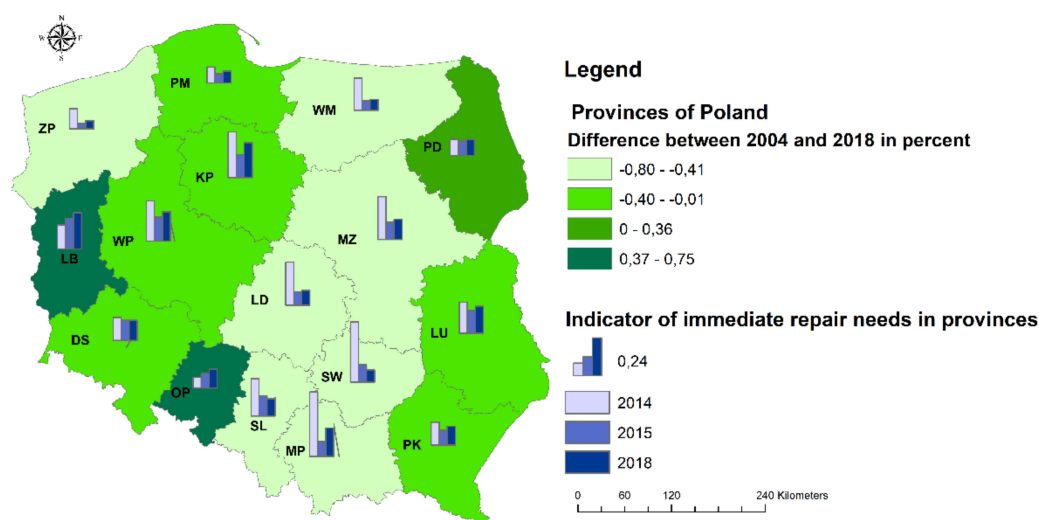


Figure 6. Immediate repair needs in provinces. Source: the authors, based on [64].

Only two provinces reported a noticeable increase in the immediate repair needs indicator between 2004 and 2018—above 37%. This means that the road network in Opolskie (OP) and Lubuskie (LB) seems to be in a worse condition in 2018 in relation to 2004. Nonetheless, the Opolskie (OP) province did score a value below the average of 0.15 in 2018 (0.14), whereas the value of the indicator for Lubuskie (LB) was actually the highest (0.27), increasing by 50%.

Considering only 2004, the highest values of this indicator were reported in the Świętokrzyskie (SW) and Małopolskie (MP) provinces, where they reached 0.45 and 0.48,

respectively. It should be emphasised that the indicator's value for Świętokrzyskie (SW) decreased the most in 2018 (over 80%). In 2015, the highest value was noted for Lubuskie (LB) (0.23), but it was twice as low as the highest value in 2004. In 2018, the maximum values of the indicator were higher—they rose above 0.20 in four provinces (Kujawsko-Pomorskie (KP), Małopolskie (MP), Wielkopolskie (WP) and Lubuskie (LB)). These changes seem to be related to the motorway network in Małopolskie (MP), Wielkopolskie (WP) and Lubuskie (LB), as well as long-term unfinished investments taking place in Kujawsko-Pomorskie (KP).

As Figure 6 shows, the situation in Podlaskie (PD), Lubelskie (LU) and Dolnośląskie (DS) is more or less stable, because the difference between the rates in 2004 and 2018 is not more than 15%. Generally, the state of the Polish road network according to changes observed in values of the immediate repair needs indicator improved by 27%, even though the difference between 2015 and 2018 was, on average, unfavourable.

It was assumed that the greater the efforts and funds committed, the better the results would be, such as a growing share of roads in good condition, decreasing share of the worst class roads and a lower indicator of the immediate repair needs. On the other hand, the opportunities which EU funds offer (emphasising the role of international and regional road networks) may encourage the national and regional governments to overinvest in this transport type, while other options might seem to be neglected in development strategies. Thus, regional transport development will not gain in sustainability. Moreover, in lagging areas, investing only in long-distance connections may provide incentives for the main economic assets of the region to relocate elsewhere [37], which affects the development of the region.

For this reason, the study included the measures of engagement and fund allocation on the 'planning side' and their comparison with outcomes reported thus far in terms of the condition of road networks after the completed EU financial perspective 2007–2013. Hence, five characteristics (ratios) were compared (Table 3):

- (1) R1—funds engaged in road infrastructure development between 2007 and 2013 (with the use of EU funds) within provincial borders, standardised by dividing them per km²,
- (2) R2—involvement in road infrastructure development,
- (3) R3—immediate repair needs in provinces in 2015 (due to the prolonged implementation of the initiated projects),
- (4) R4—difference between the share [%] of roads in the best state in 2006 and 2015,
- (5) R5—difference between the share [%] of roads in the worst state in 2006 and 2015.

Table 3. Road transport development evaluation—main characteristics (ratios) obtained for provinces. Source: the authors.

Province	R1	R2	R3	R4	R5
Dolnośląskie (DS)	275,730.33	0.34	0.11	−10.70	−0.70
Kujawsko-Pomorskie (KP)	188,588.28	0.53	0.17	11.00	−9.00
Lubelskie (LU)	173,631.07	0.17	0.07	7.10	−2.80
Lubuskie (LB)	269,879.11	0.19	0.15	−3.10	4.30
Łódzkie (LD)	592,711.54	0.07	0.13	21.80	−27.40
Małopolskie (MP)	432,308.01	0.23	0.11	25.40	−28.70
Mazowieckie (MZ)	444,077.70	0.16	0.17	8.20	−16.80
Opolskie (OP)	3708.48	0.32	0.10	9.40	−5.70
Podkarpackie (PK)	484,482.35	0.48	0.07	16.00	−17.00
Podlaskie (PD)	157,560.68	0.05	0.11	4.00	−5.40
Pomorskie (PM)	134,504.67	0.18	0.18	17.10	−9.70
Śląskie (SL)	710,833.25	0.05	0.11	−0.20	−8.10
Świętokrzyskie (SW)	173,828.57	0.09	0.04	6.80	−17.10
Warmińsko-Mazurskie (WM)	155,893.85	0.33	0.13	17.80	−20.90
Wielkopolskie (WP)	160,041.06	0.18	0.15	3.70	−4.70
Zachodniopomorskie (ZP)	78,902.69	0.07	0.23	22.10	−11.50

In the next step, these values were arranged into five classes, where the most desirable values were classified into the fifth class and the least favourable ones were in the first class. Hence, the classification differs for R1, R2 and R4 (where ‘more is better’) when compared with these made for R3 and R5. The limits of the classes were determined on the basis of statistical methods. The mode for classifying features within the classes was Jenks’ Natural Breaks. Table 4 presents the classification results for the provinces, including the median value in the last column (the higher the median, the better the results of road investments).

Table 4. Road transport development evaluation—classification. Source: the authors.

Province	R1	R2	R3	R4	R5	Median
Dolnośląskie (DS)	3	4	4	1	2	3
Kujawsko-Pomorskie (KP)	2	5	2	3	3	3
Lubelskie (LU)	2	3	5	3	2	3
Lubuskie (LB)	3	3	3	2	1	3
Łódzkie (LD)	5	2	3	5	5	5
Małopolskie (MP)	4	3	4	5	5	4
Mazowieckie (MZ)	4	3	2	3	4	3
Opolskie (OP)	1	4	4	3	2	3
Podkarpackie (PK)	4	5	5	4	4	4
Podlaskie (PD)	2	1	4	3	2	2
Pomorskie (PM)	2	3	2	4	3	3
Śląskie (SL)	5	1	4	2	3	3
Świętokrzyskie (SW)	2	2	5	3	4	3
Warmińsko-Mazurskie (WM)	2	4	3	4	4	4
Wielkopolskie (WP)	2	3	3	3	2	3
Zachodniopomorskie (ZP)	1	2	1	5	3	2

In light of the values presented in Table 4, the Łódzkie (LD) province gained the median equal 5 owing to the highest expenses on road development accompanied with an increase in the share of roads in the best condition and a noticeable decrease in the share of roads in the worst condition.

However, the indicator for immediate repair needs is average, and the involvement of regional authorities may be qualified as less than average. Overall results seem to be much better in the Podkarpackie (PK) province, where the median is 4, and all the results fall in the fourth and fifth classes. In this province, less of the funds spent on road transport development resulted in satisfying road condition improvement, and this is related to the involvement factor. The worst results are in the Podlaskie (PD) province, where the road conditions have not changed much since 2006 and the province seems to be less engaged in transport development. A similar situation has been noted in Zachodniopomorskie (ZP), where the fewest funds were used. Nevertheless, the share of roads in good condition have increased. An analysis of the results from Table 4 and Figure 7 shows the highest median (5), and thus the highest road transport development evaluation, in the Łódzkie province. The lowest level (2) was recorded in the Podlaskie (PD) and Zachodniopomorskie (ZP) provinces. The Podkarpackie (PK) and Małopolskie (MP) provinces reached level 4, and the remaining provinces were scored at level 3. Figure 8 presents the aggregated results of road transport development evaluation for the Polish provinces.

Figure 9 shows the standardised indicators in one scale for each single R—Road transport development evaluation presented as rasters.

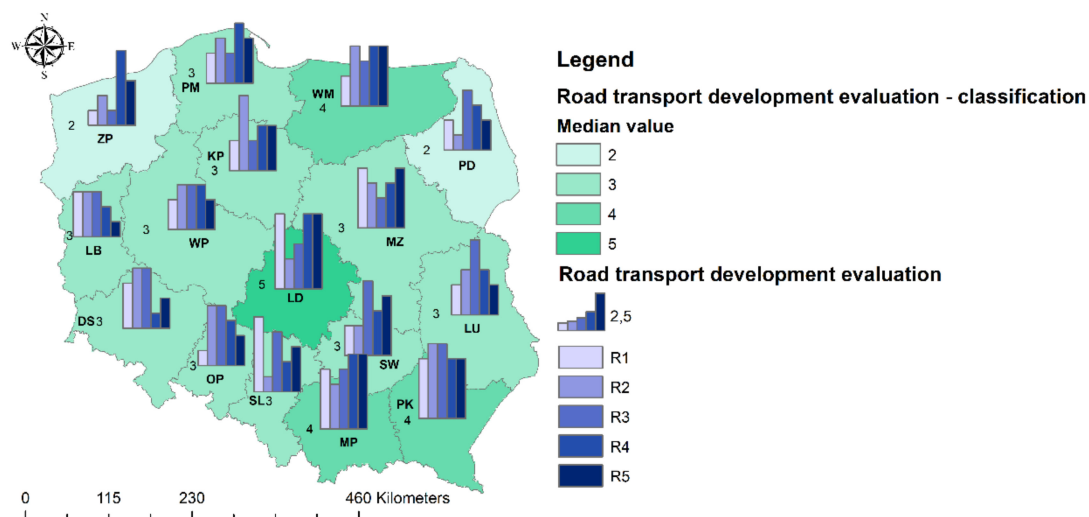


Figure 7. Road transport development evaluation—classification. Source: the authors.

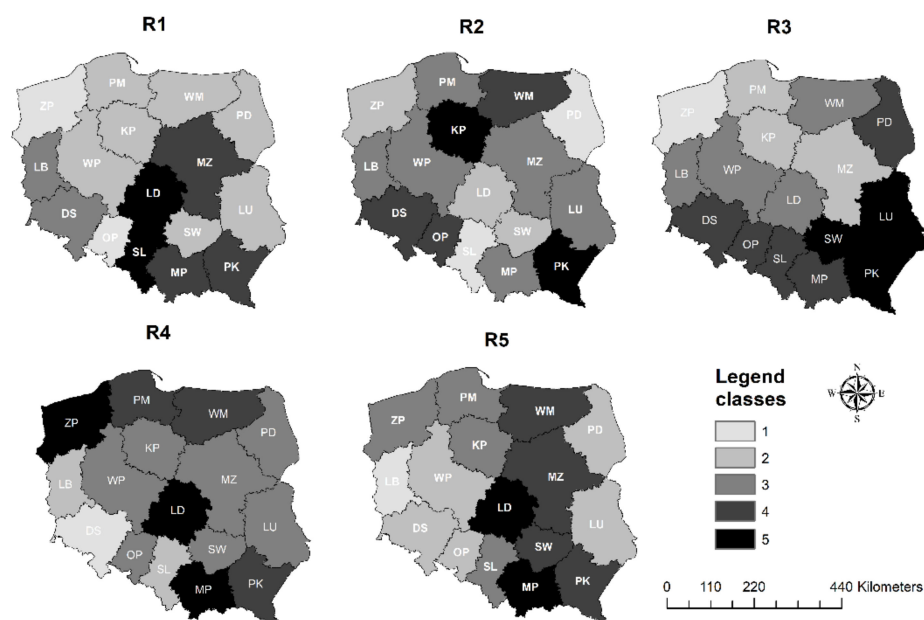


Figure 8. Road transport development evaluation. Source: the authors.

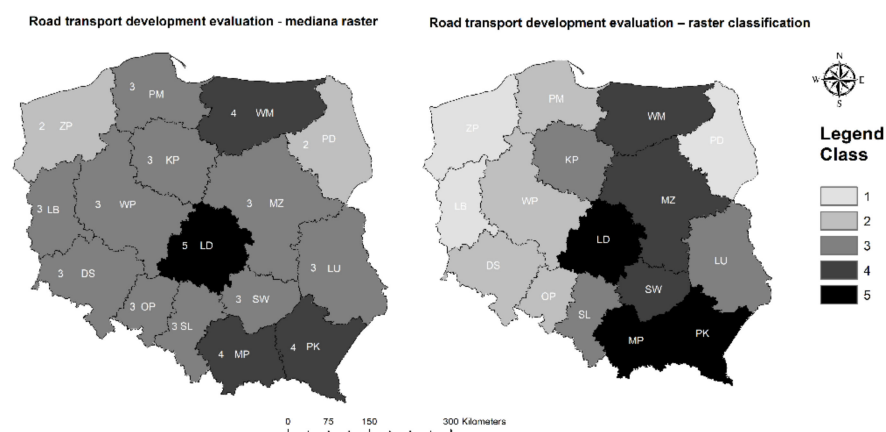


Figure 9. Comparison of results of the road transport development evaluation. Source: the authors.

In Figure 9, the results of a vector analysis where the parameter was the median were converted to a raster on the same scale as the raster analysis. As expected, the results are different, because the median was the statistical parameter in the vector analysis and the expected value in the raster analysis. The use of the median resulted in a more flattened division, as the number of intervals was reduced (no class 1 was distinguished), and hence there was less differentiation between the provinces. In the raster analysis, this level was achieved in the Podlaskie (PD), Zachodniopomorskie (ZP) and Lubuskie (LB) provinces, which in the vector analysis were assigned to level 3. The highest level in both studies was reported in Łódzkie (LD), although this level in vector analysis occurred only in this province, whereas in the raster analysis, two other provinces, Podkarpackie (PK) and Małopolskie (MP), reached this level. The Warmińsko-Mazurskie (WM) province reached level 4 in both analyses, while the Mazowieckie (MZ) and Świętokrzyskie (SW) were shifted to another level in the raster analysis. The Kujawsko-Pomorskie (KP) and Śląskie (SL) provinces were on the same level in both analyses, while the Pomorskie, Wielkopolskie, Dolnośląskie and Opolskie provinces fell by one level to class 2 in the raster analysis.

4. Discussion

This study shows sustainable transport development to be an important part of the sustainable development process with respect to basic management functions: (a) planning—where this issue is considered in sustainable development strategies; (b) organisation—by creating and implementing projects with the aim of transport network improvement; and (c) controlling—reporting and comparing the effects of the projects and allocation of funds. Hence, sustainable transport development was considered from a wider perspective, with a special emphasis on purpose and effect connection rather than comparing popular indicators concerning travel costs, time or safety.

For the purpose of this research, the cartographic methods and abilities of GIS tools were applied. The analyses conducted in this study aimed to evaluate the involvement of Polish regions in sustainable transport development, and to show direct and indirect results, such as road system improvement. As arises from the conducted research, sustainable transport development was a key goal in regional policy and development in 2004–2018. Most Polish provinces treated this as a priority in terms of expenditures and commitment. They followed guidelines from the EU and Polish transport policies and implemented them in regional policies.

As can be inferred from the previous parts of this article, this tendency to invest most of the funds allocated to transport development into road network improvement is noticeable in almost every Polish province. Therefore, the improved road network seems to be the result of a plan, and the engaged funds are sources used for achieving this goal.

Transport development in Poland in the EU financial perspective 2007–2013 was focused on the road network. The justification for these actions cannot be denied, because the network needed renovation and expansion [54,66]. Although the improvement to the road network after the completion of the projects implemented in this perspective is significant, sustainable transport development should equally include other forms and means of transport. However, the need for transport development in post-socialist countries is so high that it is difficult to finance them using funds from one EU financial perspective. Most national and regional governments have to choose between immediate needs and those that are less urgent.

Despite allocating considerable funds to peripheral regions in post-socialist countries (and the EU members), these parts of Europe appear to be particularly underinvested in terms of transport, also at the local and regional levels. Although political transformations in Central and Eastern Europe occurred nearly three decades ago, most of these countries are still in need for regionally oriented investments. In Poland, interregional differences peaked in 2010–2015, as a result of increased engagement in priority investments (i.e., the A2 Łódź–Warsaw motorway, in particular) [66]. According to the results of analyses conducted in this study, most of the Polish provinces have more or less reached their key

goal (road network improvement). Hence, the applied methodology makes it possible for us to evaluate the effects of these activities in comparison to the funds involved at the NUTS 2 level. Such comparison is essential for the purpose of future transport planning and allocating funds more directly and effectively.

Much more definitely needs to be done in terms of monitoring and reporting progress in the development of various types of transport infrastructure and in predicting the expected results. This is why decision-makers should be able to take advantage of new tools such as geographic information systems, especially given that most of the data have already been partially reported and can be included in databases without significantly increasing costs.

The INSPIRE Directive enables the scope of data to be harmonised, and the data to be made available for the purpose of assisting legislators in taking decisions and actions. The number, type and scope of these properties are determined by each EU Member State's needs [71]. The authors suggest using the INSPIRE Geoportal, as it is the central European access point to the data provided by EU Member States and several EFTA countries under the INSPIRE Directive [72].

The NUTS 2 level, which corresponds to provinces in Poland, is suitable for monitoring, which is confirmed by the research conducted in this article. However, each EU country should be analysed in detail in order to select the appropriate NUTS level for the purpose of future comparative analyses in different EU countries. The Community Research Centre of the European Commission, which creates the INSPIRE Geoportal for the Community countries, assumes data reliability and data sharing to be its main objectives. The methodology developed by the authors could be a tool and a source of comparable information for the European spatial information infrastructure.

5. Conclusions

The methodology applied can be employed to draft regional transport policies, plan transport services, and introduce an integrated planning approach to transport development. It is particularly important to develop a system for monitoring the level of EU fund allocation with the use of GIS tools and the capabilities of geographic information systems before the next seven-year EU budget perspective. Such in-depth analysis would be useful for regional governments and decision-makers in creating and updating long-term transport policies, as well as monitoring long-term regional development strategies. Thus, in our opinion, analyses as to whether the transport development is sustainable and addresses the actual needs should be conducted periodically with the use of GIS capabilities and dedicated geographical information systems such as INSPIRE Geoportal.

The selection of indicators largely was largely dependent on the availability and detail of source documents, which was identified as a main study limitation. Additionally, the periods of regional planning and the EU financial perspective often do not coincide, resulting in an additional limitation of the analysis and the need to use auxiliary measures. If the planning periods were unified, it would improve the comparison between regions.

This study has potential for development in the sense that the economic and social, as well as environmental, aspects of sustainable transport development can be evaluated. It seems that excessive development of the road network is not conducive to environmental protection, and therefore future measures in transport development should be with more ecological means. It is especially important in view of the recently concluded A European Green Deal and one of its targets—'rolling out cleaner, cheaper and healthier forms of private and public transport' [73].

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Ada Wolny-Kucińska and Marek Ogryzek; supervision, Marek Ogryzek and Ada Wolny-Kucińska, project administration, Marek Ogryzek and Ada Wolny-Kucińska. All authors have read and agreed to the published version of the manuscript.

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