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Quantification and Assessment of Sustainable Urban Mobility Development in Selected EU Countries Using a Composite Index

Abstract: The paper quantifies and assesses the level of sustainable (green) urban mobility development in selected countries of the European Union. For this purpose, key indicators describing different areas of green transport in the years 2011–2020 were constructed. The analysis used available public data and applied Hellwig's dynamic taxonomic method. The results of the analysis made it possible to answer the following research questions: 1) "What is the status and dynamics of green transport development in the countries studied?", 2) "Which countries in the EU are leaders in sustainable transport and why?", 3) "What determines the differentiation and development of green urban mobility in the countries studied?". The results of the study show that, despite the spatial polarisation of development, there is a structural similarity that characterises the countries with the highest and lowest levels of sustainable mobility development. A strong group is formed by the Scandinavian countries, Belgium (the leader), Hungary, Austria, Denmark, and the Czech Republic. In the years 2011–2020, a decline in the level of development in the sustainable transport sector can be observed, caused, among others, by the effects of the global financial crisis in the years 2011–2014. In contrast, the years 2015–2020 brought a dynamisation of the growth of green transport. Analysing the determinants of this development, it can be noted that, despite the efforts made, European transport policy still faces many challenges, especially due to the steady increase in greenhouse gas emissions in this sector. In addition, regional specificities and differences in transport models risk undermining the results of the European Union's efforts in this field.

Keywords: development of sustainable transport, urban mobility, measures of green transport, regional diversity, European Union countries, composite index

JEL: C4, F14, F18, Q01, Q27

1. Introduction

The rapid increase in the number of motor vehicles, the expansive exploitation of non-renewable natural resources (mainly oil), and the emission of pollutants from, among others, the combustion of diesel fuels all contribute to the destruction of ecosystems, which ultimately threatens human health (Badach, 2020). On the other hand, the poor organisation of the transport system, including the lack of efficient traffic control and management systems, as well as the low competitiveness of public mass transport vis-à-vis individual car transport, leads to the occurrence of the phenomenon of increasing congestion, threats to the safety of road traffic participants (including pedestrians and cyclists), and lowered technical standards of roads and road infrastructure facilities (Tsavachidis, Petit, 2022).

Official test results show that modern vehicles are increasingly energy efficient and produce less pollution, but there are many doubts about how emissions are measured. The test procedures used in 2014 in the EU were last updated in 1997, and cars and vans under on-road conditions often emit much higher amounts of CO_2 than in the lab. Research conducted by the International Council on Clean Transportation (ICCT) shows that actual CO_2 emissions are about 40% higher than measured in the testing laboratory, and overall emissions generated by the EU transport sector in 2014 were 20% higher than in 1990 (The European Environment Agency, 2019). Moreover, in 2020, road transportation was the main source of nitrogen oxide air pollution, accounting for 37% of emissions (The European Environment Agency, 2022). At the same time, according to EU data, nearly 380,000 premature deaths in 2020 can be attributed to air pollution. Emissions of harmful compounds from road transport also contributed to huge health costs, valued at €67–80 billion annually in the EU (European Federation for Transport and Environment, 2023). It is estimated that the environmental costs of transportation account for about 28% of external costs, equivalent to 6% of GDP (Ministerstwo Infrastruktury, 2019). In turn, data for 2019 shows that the average value of the traffic noise index in the European Union (EU) was about 55 dB (with a permissible limit that does not adversely affect human health of no more than 50 dB measured in energy equivalent, averaged over an entire day, European Parliament and of the Council, 2002), and exceeding the recommended limit is a problem for nearly 125 million people, or a quarter of Europeans. Noise pollution in Europe causes 43,000 hospitalisations a year and about 10,000 premature deaths (The European Environment Agency, 2019). The European Union also pledged to improve road safety, with the goal of reducing road deaths by 50% by 2020 compared to 2010 levels. An annual decrease of 6.7% between 2010 and 2020 was needed to achieve this goal. Nevertheless, since 2010, road deaths in the EU have fallen by 19%, or 3.4% on average per year (European Parliament, 2023a). The data thus shows that traffic fatalities in Europe still generate more than 20,000 deaths a year (European Transport Safety Council, 2022).

One of the proposed solutions to eliminate the described risks and achieve the goal of protecting the climate and improving the quality of life in European cities is to dynamise the development of so-called 'green' (sustainable) transport (European Commission, 2021a). Nevertheless, cities face a number of challenges, including those related to monitoring progress in terms of sustainable urban mobility measures through indicators. Data collection requires administrative and financial resources, and cities often have difficulty accessing data held by national and regional authorities and other bodies. Hence, countries should have an integrated system of open-access data and facilitate the exchange and use of data to improve municipal systems for monitoring and programming green transport development policies (European Commission, 2023).

This paper attempts to quantify and assess the degree of development of sustainable urban mobility in selected 25 European countries. For this purpose, key indicators describing the various areas of green transportation were constructed. The data cover ten years (from 2011 to 2020). They were obtained from the public (open) databases of Eurostat, the World Bank, the European Environment Agency, and the statistical offices of individual countries. The temporal scope of the research undertaken was determined not only by the completeness and continuity of statistical information but also by an attempt to verify the impact of the occurrence of economic crises on the transportation sector (the US financial crisis and the COVID–19 pandemic). In the analysis conducted, an aggregate measure of green mobility based on a dynamic version of Hellwig's taxonomic method was constructed. The results obtained made it possible to answer the following research questions:

2. What is the status and dynamics of green transport development in the countries studied?

1. Which countries in the EU are leaders in sustainable transportation and why?
2. What determines the differentiation and development of green urban mobility in the countries studied?

Despite the widespread interest of researchers in the subject of greening transportation, so far no universal and accessible (based on open access data) set of indicators monitoring the development of the phenomenon has been defined. The measure constructed in this publication and the quantification and assessment of the development of green urban mobility carried out is a proposal for an innovative and comprehensive study that can yield important and high-quality information on changes in the quality and attractiveness of services in this area of transport in selected EU countries.

3. Sustainable (green) mobility – the definition, assumptions and quantification

3.1. The definition and assumptions of green transportation

The concept of environmentally sustainable urban transport was defined by the European Union for the first time in 2000 in the document entitled *Defining an environmentally sustainable transport system*. According to experts, this transport system is, among others, to ensure the availability of transportation based on the principles of sustainability (transportation is to be safe, non-threatening to human health and serving the natural environment for the present and future generations); it allows for efficient functioning, offering a choice of transportation mode and leading to economic development of the area; it reduces emissions of harmful substances, noise and waste, and it minimises the existence of inefficient technical infrastructure (European Commission, 2015). In 2001 the EU put forward transport policy objectives and solutions to promote the idea of urban sustainable transport relating to: a high level of mobility across the EU, energy security and protection of passengers and citizens, and the introduction of innovations to implement environmental protection (European Commission, 2012). Moreover, the European Commission issued a communication entitled *Keep Europe moving – sustainable mobility for our continent*, which focuses mainly on the aspect of helping Europeans move efficiently, effectively and ecologically (Commission to the Council and the European Parliament, 2006). The White Paper *Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system*, published in 2011, which refers to the modern

Europe 2020 Strategy, highlighted the importance of sustainable transport for the development of the EU and placed great emphasis on reducing pollutant emissions (by 60% by 2050) and reducing the EU's dependence on oil imports. It was agreed at the time that the future of urban transportation should be based on, among others, an efficient network of multimodal travel between cities and the greening of urban transport (Malasek, 2016: 876–885). In 2013, the Urban Mobility Package introduced Sustainable Urban Mobility Plans (SUMPs) as a framework for cities to plan and implement responses to urban mobility policy challenges. Since then, the Commission has encouraged the widespread adoption of SUMPs as the basis of European urban mobility policy. Moreover, the SUMP guidelines have been widely used by local authorities, planners and stakeholders. It has proven to be an effective, robust and flexible tool that cities can rely on when planning urban mobility measures (Sydorów, 2023: 9–21). In 2016, in its communication *European Strategy for Low-Carbon Mobility*, the European Commission proposed measures to accelerate the decarbonisation of European transport and the achievement of zero-emission, thus aiming to fulfil the goal set out in the White Paper and, at the same time, contribute to the goals of the Paris Agreement (COP 21) (European Union, 2016). Consequently, the Sustainable and Smart Mobility Strategy was presented in December 2020, along with a plan that includes 82 initiatives to guide the work until 2024 (COM(2020)0789). The document lays out actions to put European transportation on the path to a sustainable and smart future. The scenarios underlying the strategy assume that the effects of the actions could reduce emissions from transportation by 90% by 2050 (European Union, 2020). In July 2021, in its communication *New EU Urban Mobility Framework* (European Commission, 2021b), the Commission presented a series of proposals and legislative reviews in the area of transport decarbonisation in line with the Green Deal goal of achieving climate neutrality and a 90% reduction in greenhouse gas emissions from transport by 2050 (European Parliament, 2023b). The Commission also emphasised the importance and promoted the need to implement SUMPs by establishing a national support framework to align local sustainable urban mobility plans more closely with the SUMP concept (European Commission, 2023).

Adherence to the above-presented strategies is one of the key elements in the development of sustainable mobility in Europe's cities. Particular attention should be paid to improving the efficiency of various forms of transportation. The optimal solution would be to use all modes of transport, alone and in combination (co-modality, intermodality), by adjusting the capabilities of each to create more efficient transportation systems, i.e., transportation that reduces pollution levels in cities and guarantees sustainable mobility of people and goods. The aim of EU actions should therefore be to create an international transport network and improve safety, thus striving for sustainable and coherent development of EU countries (Locat Partnership, 2023, Figure 1).

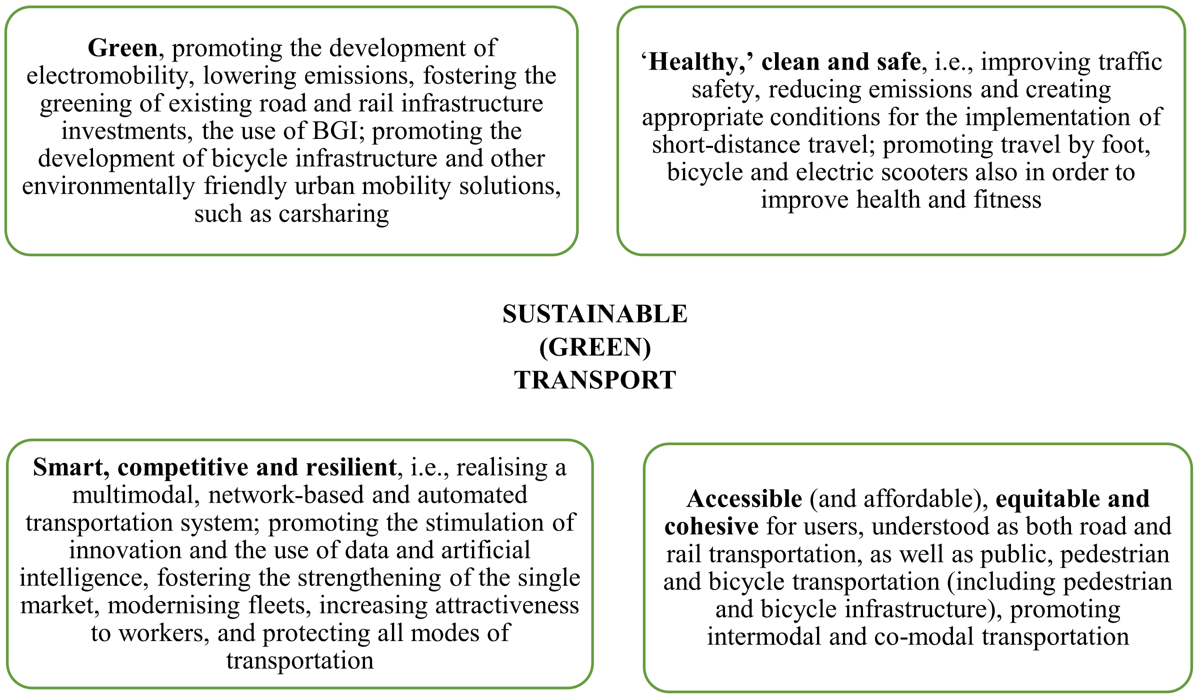

Figure 1. The areas of measures implemented for the development of a sustainable low-carbon urban transport system in the EU
Source: own elaboration based on the cited literature

In the literature, the concept of green transportation is often equated with green or sustainable transportation and green mobility. Green mobility is often associated with modern technologies to be used in means of transportation so that both private vehicles and public transportation emit less harmful gases into the atmosphere. The development of green mobility is intended to support the realisation of the principles of sustainable socioeconomic development, assuming that transportation activities are carried out so as not to cause irreversible changes to the natural environment. The concepts of green transportation and green mobility assume that green transportation solutions are those that are environmentally friendly (Motowidlak, 2022: 233–246), and the main premise of EU actions in this area is to implement such solutions that will lead to the greening of the transport system, including its decarbonisation (Britannica, 2022), and to greater cleanliness in the mobility sector, and thus to safety and health in cities (European Union, 2022). The concept of urban ecomobility is also emerging in the literature. This definition encompasses not only electric and low-emission vehicles but also all the elements that facilitate their use. Ecomobility consists of green initiatives, comprising the use of renewable energy sources and modern infrastructure. Ecomobility solutions include bicycles, personal transportation devices and other sustainable forms of transportation, such as carsharing (NewsAuto, 2020). Also associated with green transportation and ecomobility is the concept of e-mobility, which refers to the development of electric, hybrid and hydrogen fuel cell-powered propulsion systems forming the so-called 3E concept, and is thus understood as both electromobility and ecomobility, but also the economics of mobility. Each of these three elements represents mobility (the ability to operate or move efficiently and flexibly) in different terms (Słownik języka polskiego PWN, 2023). The paper assumes, following Burdzik et al. (2017: 17–29), that sustainable (green) urban mobility means a kind of transportation that is safer and friendlier to its surroundings (leading to the improvement of the quality of life of urban and rural residents) and the natural environment and that is also a source of resilience and competitive advantage for a given economy, as an alternative transport which is cheap, relatively fast, and more reliable.

3.2. Quantification

In the literature and strategic documents, one can find indicators proposed for measuring sustainable urban transportation, as well as a wide range of suggested elements that should be included in the analyses (Urbanek, 2019: 61–80). According to a list published by the Transportation Research Board of Canada, any indicators describing green transportation ought to be based on the principle of sustainability and should be taken into account in the process of managing and assessing public transportation development (Litman, Burwell, 2006; Litman, 2007). In doing so, it emphasised that the principle of sustainable development aims to protect natural resources and ecological systems, and therefore favours green transportation policies, which in turn minimise the consumption of environmental resources. Canadian researchers say that, when choosing indicators, it is also important that the measures address different areas of analysis, i.e., decision-making (quality of planning), transportation impacts on quality of life and the environment, and any economic impacts. Thus, indicators were proposed relating to, among others, the volume of pollutant emissions, the number of people exposed to road noise, social and environmental costs, consumer spending on transportation, frequency of travel by public transportation, and the number of deaths and injuries sustained in traffic accidents (Litman, 2008; Ramani et al., 2009; Ramani, 2018: 103–92).

The European Commission (EC) has unveiled its own set of Sustainable Urban Mobility Indicators (SUMI) which describes sustainable urban mobility in a practical and effective way. Examples of indicators identified by the EC include air pollutant emissions, road safety (the number of accidents, injuries and fatalities), social accessibility of urban transportation for different user groups (people with disabilities, mothers with children, young people, working people), traffic noise, energy and economic efficiency, as well as passenger satisfaction with public transportation. The indicators make it possible to document progress and standardise the way sustainable urban mobility is measured in Europe, and to identify areas in need of improvement (European Commission, 2020a).

The OECD (Organisation for Economic Co-operation and Development) Working Group on the State of the Environment (WGOSE) (European Commission, 2020b) divided the indicators into groups defining the transport sector into thematic scopes and described their impact on the environment. Each group presents more than a dozen indicators that, taken together, constitute a very comprehensive group of measurable and non-measurable elements that are helpful in integrating environmental aspects into transportation policy. It took into account, among others, trends in passenger transportation, the length of the road and rail network, final energy and fuel consumption by the transportation sector, indicators describing air pollution, water pollution, noise levels, traffic hazards, and the importance of transportation policy, including the social cost of transportation, road user fees, or environmental and technical infrastructure expenditures (OECD, 1999).

At the international level, databases and sets of indicators have been established that can be used in assessing sustainable transport, e.g., the database of indicators for monitoring sustainable development (Eurostat, 2023), indicators for monitoring the implementation of the objectives of environmental strategies and environmental reviews of Member States (OECD, 2023), indicators for monitoring the progress and effectiveness of the integration of environmental and transport policies (The European Environment Agency, 2023), and a set of environmental and sustainability indicators in the UN database (United Nations, 2023).

Table 1 contains proposals for the scope of indicators in each area of sustainable transport.

Table 1. Proposal for creating indicators in each area of sustainable urban transport

The area of indicator development	Thematic scope of indicators
Accessibility, equity, cohesion	Infrastructure facilities of a given area; travel distance; travel time; cost of travel; capacity of linear and point infrastructure; supply of transportation services; vulnerability of infrastructure; accessibility of transportation infrastructure; reduction in the cost of access to infrastructure; multimodal transportation system.

The area of indicator development	Thematic scope of indicators
Ecology, environmental protection	Electromobility; electrification of public and individual transport; environmentally friendly transport and infrastructure solutions, environmentally friendly urban mobility solutions (carsharing, Bike and Ride; Kiss and Ride, Park and Ride, mobility hub; personal transport devices).
Health, safety, quality of life	Volume of gaseous and particulate emissions; monitoring of emission reductions; development of rail, bicycle, and public transportation; energy consumption in transportation; cleaning up and restoring urban space to pedestrians; proximity to parks as well as bicycle and pedestrian infrastructure; transportation congestion; safety of road users.
Competitiveness, resilience, smart growth	Transportation employment, investment; digitalisation of transportation; attractiveness of public transportation; innovative transportation and infrastructure solutions; digitalisation and smart traffic management systems; applications and situation monitoring; preferential allocation of transportation tasks, development of services and efficient communication with the environment; sustainable creation and planning of traffic space.

Source: own elaboration based on the cited literature

4. Data and research methodology

4.1. Data

In order to quantify and assess the degree of development of sustainable transport in selected EU countries, 13 sub-indicators were constructed. They were based on available public data for the period 2011–2020 obtained from Eurostat, the European Environment Agency, the World Bank, and state statistical offices. Finally, twelve measures met the formal criteria (collinearity, correlation and variation). Thus, the proposed set of indicators (destimulants and stimulants of green mobility development, Table 2) provides simultaneous application and comparative opportunities covering areas of sustainable urban transportation (Figure 1, Table 1). The study was conducted for 25 EU countries: Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Spain, the Netherlands, Ireland, Lithuania, Luxembourg, Latvia, Germany, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, Hungary, and Italy. It was initially intended to cover all Member States (27 countries), but Malta and Cyprus were not included in the study due to the availability of statistical data.

Table 2. Indicators characterising sustainable mobility in selected European countries

Proposed area of indicator development	Indicator (unit)	Description	D/S	$\overline{x}$	SD	CV
Accessibility, equity, cohesion	Number of passenger cars (per 100,000 inhabitants)	The indicator is defined as the number of registered passenger cars.	D	4.6	1.1	24
	Number of rail passengers (per 1 million inhabitants)	The indicator determines the number of passengers carried by the railroad.	S	693.0	1941.6	280
Ecology, environmental protection	Share of low-emission vehicles in the number of newly registered passenger cars (%)	Low-emission vehicles include plug-in hybrid-electric vehicles (PHEVs), which combine the features of an internal combustion car and an electric car, all-electric cars, including battery electric vehicles (BEVs), hydrogen cars, and compressed natural gas (CNG) vehicles.	S	1.5	3.3	220
	Share of renewable energy consumption in gross final energy consumption (%)	Gross final energy consumption is the energy consumed by end users plus network losses and power plant own consumption.	S	6.5	4.2	65

Proposed area of indicator development	Indicator (unit)	Description	D/S	$\overline{x}$	SD	CV
Competitiveness, resilience, smart growth	Share of passenger car transport in total ground passenger transport (%)	The term passenger car also includes microcars, taxis and other rental cars, provided they have fewer than 10 seats in total. This category may also include vans designed and used primarily to carry passengers, as well as ambulances and motorhomes.	D	78.7	8.7	11
	Share of passenger transport by rail and bus in passenger transport (%)	Means of public transportation refer to buses, including coaches and trolley buses, and trains. All data are based on mobility within national territories, regardless of vehicle nationality.	S	17.7	4.4	25
	Share of employment in the transport sector in total employment (%)	Employed persons aged 15 to 64 years were included.	S	5.6	1.2	21
Health, safety, quality of life	Number of traffic fatalities, including drivers and passengers of motor vehicles, bicycles and pedestrians (per 100,000 inhabitants)	People who died in traffic accidents up to 30 days after the accident occurred are counted as traffic fatalities. After 30 days, the cause of death can be determined differently.	D	5.7	2.0	35
	Average CO_2 emissions generated by newly registered passenger cars (tons per number of kilometres driven)	Reported emissions are based on type approval and may differ from the actual CO_2 emissions of new cars.	D	124	14.7	12

Proposed area of indicator development	Indicator (unit)	Description	D/S	$\overline{x}$	SD	CV
	Greenhouse gas emissions across the transport sector (tons per capita)	The indicator measures emissions of: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Using the individual global warming potential of each gas, they are combined into a single indicator expressed in CO_2 equivalent units.	D	8.3	3.9	47
	CO pollution emitted by passenger cars (tons per year per number of registered cars)*	The indicator represents carbon monoxide (CO) air pollution in the road transport sector – emitted mainly by passenger cars.	D	0.2	0.3	121
	NO pollution emitted by passenger cars (tons per year per number of registered cars)	The indicator represents nitrogen oxide (NO) air pollution in the road transport sector – mainly emitted by passenger cars.	D	0.1	0.13	125
	Years of life lost due to PM2.5 exposure (number of years)	The indicator is defined as the number of years of potential life lost due to premature death. It is an estimate of the average number of years that one million people in the country would have lived if they had not died prematurely.	D	7705	8847.6	115

Notes: S – stimulant – higher values determine a higher level of the studied phenomenon; D – destimulant – shows the opposite effect to stimulants (Młodak, 2006).

* Means that the indicator was not included in the study; $\overline{x}$ – mean, SD – standard deviation, CV – coefficient of variation.

Source: own elaboration based on Eurostat, 2023; OECD, 2023; United Nations, 2023; The European Environment Agency, 2023

4.2. Methodology

The determination of the value of the composite index was carried out in the following stages: 1) collection of statistical information and construction of indicators that meet the substantive criteria, 2) selection of diagnostic variables – formal assessment (analysis of variation, correlation and collinearity), 3) determination of the nature of variables (stimulants, destimulants), 4) normalisation of features and calculation of the synthetic measure, 5) visualisation, tabulation and interpretation of the obtained values of the composite index.

In the construction of the measure, variables were selected that meet the variation condition |CV| > 10% (Reed, Lynn, Meade, 2002: 1235–1239) and those that are not correlated. Pearson's correlation coefficient was used to assess the degree of correlation (1), (Kot, Jakubowski, Sokołowski, 2007: 430):

$$r_{xy} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \overline{x}\right)\left(y_i - \overline{y}\right)}{\sqrt{\frac{1}{n}\sum\left(x_i - \overline{x}\right)^2} \times \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2}}, \tag{1}$$

where: *rxy* – correlation coefficient, *x*, *y* – values of the diagnostic feature for the *i*-th country, *n* – the number of the countries. The statistical significance analysis of correlation (1) was carried out using Student's t-test (2), (Kot, Jakubowski, Sokołowski, 2007: 433):

$$t = \frac{r_{xy}}{\sqrt{1 - r_{xy}^2}} \times \sqrt{n-2}. \tag{2}$$

The sensitivity of the results of the correlation analysis was verified with the use of the variance inflation factor (VIF) (Jongh et al., 2015):

$$\mathrm{VIF}_i = \frac{1}{1 - R_i^2}, \tag{3}$$

where: R_i^2 – the coefficient of determination for a multiple regression model between the *i*-th independent variable and all other predictors. It is assumed that when VIF > 10, multicollinearity is disruptive, and the variable (indicator) responsible for this should be removed (Stanisz, 2007: 865).

The results of the analysis of variance determined the inclusion of all indicators in the study (Table 2). Nevertheless, the assessment of correlation and collinearity confirmed the fact that the variable depicting the volume of carbon monoxide pollution emissions from passenger cars in the country was statistically significantly correlated with other indicators. Thus, this feature was removed from the set of diagnostic variables.

The following formula was used to normalise the variables (4):

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{OS_j}, \tag{4}$$

where: *zij* – values of normalised variables, *osj* – standard deviation (Hellwig, 1968: 307–326).

Then the indicators were divided into stimulants and destimulants, so that in the process of constructing the measure, from the values of the destimulants a quasi-pattern *φj* (minimum) was determined, and for the stimulants a quasi-pattern taking the maximum value of the feature. The construction of the measure was based on the Euclidean metric (5). On this basis, the distances of objects (*di*) from the quasi-pattern were calculated:

$$d_i = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - \varphi_j \right)^2}. \tag{5}$$

The study used a dynamic approach to Hellwig's measure of development which involved determining 'global' quasi-patterns for each feature, i.e.; maximum and minimum values for the entire study period. In the procedure for calculating the distance, the values of the quasi-patterns were taken not for each year but in the form of the minimum and maximum from among the values of the feature for the entire period under study (Brożek, Szewczyk, Jaworska, 2021: 11–24). The dynamisation of the method made it possible to create a ranking of countries and a comparative assessment of the magnitude and direction of changes in the level of sustainable mobility occurring in individual years as well as the entire period under study. Then, using formula (6), the Hellwig taxonomic measure was determined, the values of which are within the range of [0, 1]:

$$\mu_i = 1 - \frac{d_i}{d_{-}}, \tag{6}$$

where: *μi* – a taxonomic measure of green transport development for a given *i*-th country, d_ – a critical distance of a given object from the pattern (benchmark). The benchmark of development is the country with the highest values of the measure.

Groups of countries were then formed based on the quartiles. The boundaries of the first class (countries with the highest level of development) were determined by the maximum and the third quartile, the second – by the third quartile and the median, the third – by the median and the first quartile, and the fourth – by the first quartile and the minimum (Bąk, 2018: 7–20).

The *Kt* coefficient (7) was used to detect the spatial concentration of countries (homogeneous areas) in terms of green transport:

$$K_t = \frac{\left(k+\sqrt{k}\right)\cdot\sqrt{\left(\sum_{i=1}^{k} f_{i,t}^2\right)}-\sqrt{k}-1}{k-1}, \tag{7}$$

where *fi,t* – the share of the *i*-th country in the value of the total measure for the *t*-th period (*i* = 1, 2, …, *k*; *t* = 1, 2, …., *n*), *k* – the number of analysed countries, *n* – the number of periods. The degree of concentration will be determined according to the following scale: low when the *Kt* coefficient takes values within the range [0.0–0.2], medium when the coefficient is in the range [0.2–0.5], and high when the coefficient is equal to at least 0.5 (Czempas, 2012: 69–81).

Calculations and visualisation were performed in IBM SPSS Statistics v.20andArcMap v. 10.8.2.

5. Analysis results

The obtained results of the analysis show an annual decrease in the level of green transport development in the years studied of about 0.8% (Figure 2a). At the same time, between the years 2011 and 2020, there is a high level of variation among countries in terms of the phenomenon (about 16%), as well as an average annual slight increase (of 0.01%) in the variation of sustainable mobility development (Figure 2b). Moreover, a particularly dynamic downward trend in the level of development was observed between the years 2011 and 2014 (a decrease of 4.2% year-on-year) and a clear (albeit slower) upward trend between the years 2015 and 2020 (an increase of 1.3%). Between the years 2011 and 2014, there was also an increasing diversification of countries in terms of sustainable transportation (an increase of 11.2%), while between the years 2015 and 2020 there was a decreasing rate of diversification (a decrease of 0.2%).

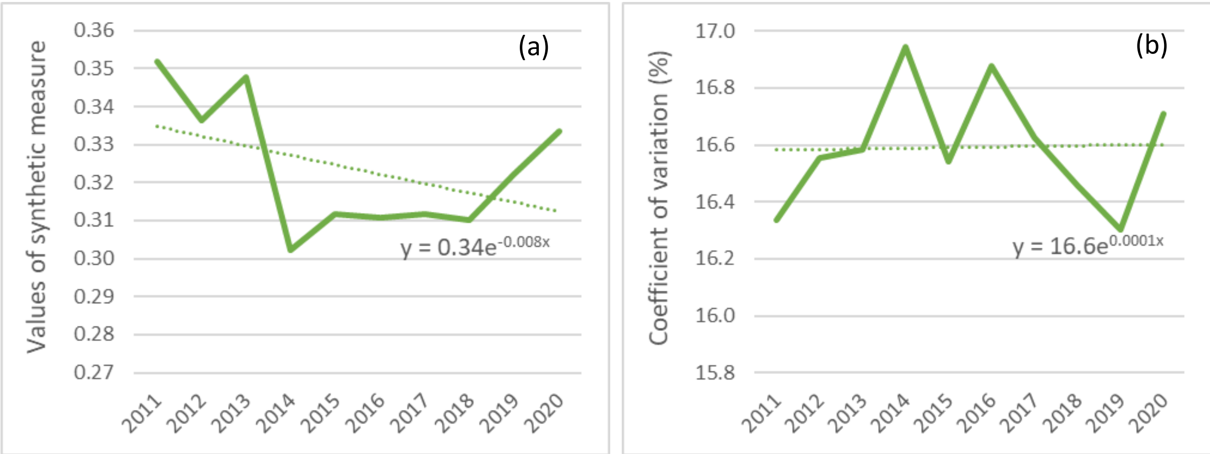

Figure 2. Trends in the development (a) and variation (b) of the level of sustainable transport in the EU from 2011 to 2020 (values of the mean and coefficient of variation of the synthetic measure)

Notes: The dashed line indicates the average rate of change (*y*), which was determined from the exponential trend function *y* = *bex*, where y is the dependent variable, which is a function of the independent values of *x*. The values of e are the basis corresponding to the exponential values of *x*, and the value of b is a constant value. The exponent of this function is approximately (when multiplied by 100%) equal to the average rate of change of the synthetic variable (Kusideł, Antczak, 2014).

Source: own elaboration

Spatial variation in the development of sustainable mobility was confirmed by the results of the spatial concentration study (Table 3). In the years 2011–2020, a weak degree of concentration of countries was observed, as measured by the *Kt* coefficient (the values of the measure ranged from 0.171 to 0.205). This result remains at a similar level throughout the studied period, which can be interpreted as the lack of homogeneous clustering of the studied countries in space.

Table 3. Spatial concentration coefficient *Kt* of green transport in the studied EU countries in the years 2011–2020

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Kt	0.171	0.181	0.174	0.205	0.198	0.198	0.198	0.199	0.191	0.183

Source: own elaboration

Despite the spatial polarisation of development, there is a structural similarity that characterises the countries in the group with the highest level of sustainable mobility development, i.e., Belgium, Sweden, Hungary, Slovakia, Austria, Denmark, and the Czech Republic (with the lowest level in Class 1 recorded in the Czech Republic and the highest in Belgium). In contrast, the countries constituting the group with the lowest level of development were Luxembourg, Lithuania, Portugal, Slovenia, Poland, Estonia and Bulgaria (Luxembourg had the lowest level of the phenomenon in Class 4 and Bulgaria the highest), Figure 3a. The data in Figure 3b show that the largest fluctuations in the scale of the phenomenon at the turn of the surveyed years were recorded in Poland, Latvia and Estonia (the development variation measured by the coefficient of variation ranged from 10.1% in Latvia to 13.3% in Poland). Relative stability in the development of sustainable transport was recorded in France, Croatia, Slovakia and Greece (coefficient values ranged from 2.9% in Greece to 5.0% in Croatia).

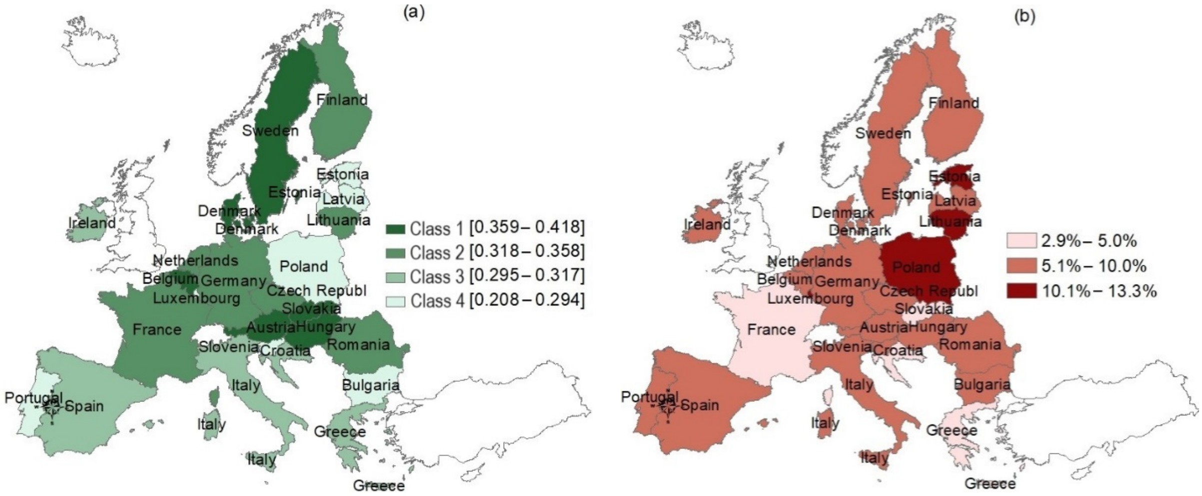

Figure 3. Average level (a) and variation (%) (b) of sustainable transport development in EU countries in the years 2011–2020
Source: own elaboration

Between 2011 and 2020, eight of the 25 EU countries analysed recorded an increase in the level of sustainable transportation. Finland and Sweden saw the largest increases (about 17% in 2020 relative to 2011). In addition to Sweden and Finland, Luxembourg (13.1%), France (11.5%) and Portugal (6.4%) were also among the countries with the largest relative growth in the phenomenon, Figure 4a. In contrast, Poland and Latvia were the countries with the largest decrease in the phenomenon (of more than 30% in Poland and more than 17% in Latvia). Five countries recorded positive growth rates of the index. The fastest average annual growth rates were observed in, respectively: Sweden, Finland and Portugal (from 1.17% in Portugal to 1.73% in Sweden). The largest annual decline was observed in Poland (about 4% year-on-year) and Denmark (of more than 2% on average) (Figure 4b).

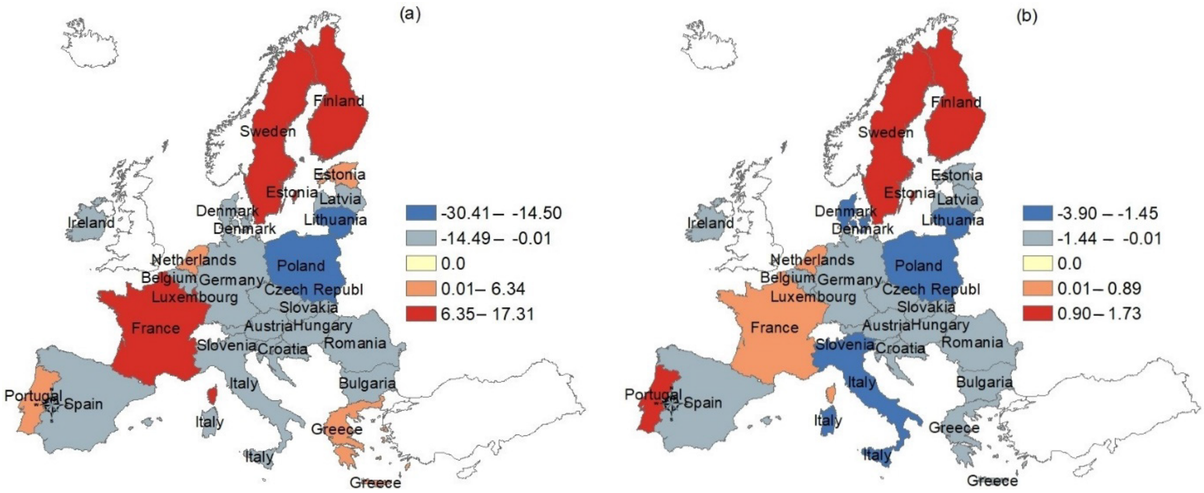

Figure 4. Change in the level of development of sustainable transport in EU countries in 2020 with respect to 2011 (a) and the rate of change in the years 2011–2020 (b) (%)
Source: own elaboration

During the initial period of the pandemic, i.e.; in the years 2019–2020, the value of the composite index of green transport increased in 18 EU countries, with the largest increases observed in Luxembourg (30%), Denmark and Sweden (about 8%). The largest decrease in the level of green transport development was observed in Poland (a decline of about 6%), Figure 5.

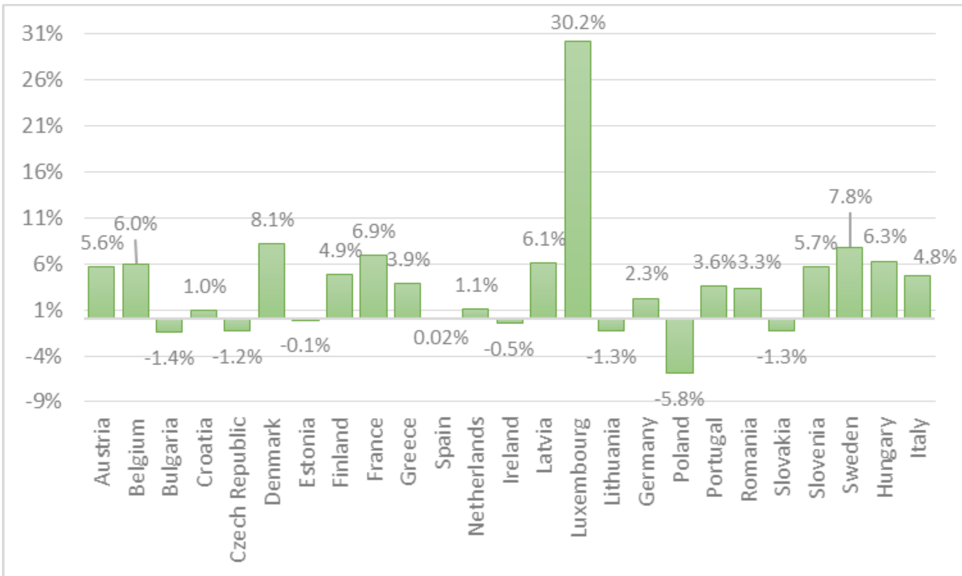

Figure 5. Change in the level of development of sustainable transport in 2020 with respect to 2019 (%)
Source: own elaboration

6. Discussion

The recorded decline in the level of sustainable transport development and the slowdown (instability) in the pace of this development in the analysed EU countries in the years 2011–2014, and the subsequent dynamisation of the transport industry in the years 2015–2022 are, among others, the result of the financial crisis initiated in 2007 in the United States (Krugman, 2009). The stock market crisis revealed the weaknesses of the global market and its low resilience to shocks. The global nature, in turn, meant that the crash encompassed the entire world economy and most of its fields, including the activity of the transport sector, also in terms of green mobility. Between 2009 and 2013, there was a downturn, and transport, as a sector of the economy that determines economic and social activity, was and still is particularly sensitive to fluctuations in demand resulting from the stages of the business cycle (Załoga, 2012: 325–330).

During the years 2019–2020 (the initial period of the COVID–19 pandemic), green mobility expanded in most of the EU countries surveyed, but at the same time spatial variation increased. On the one hand, the outbreak of the pandemic prompted authorities around the world (including Europe) to impose restrictions, e.g.: by partially or completely closing their borders to passenger transport, which significantly affected the operation of all modes of transport (Smolarski, Suszczewicz, 2021: 121–140). On the other hand, in European countries, the pandemic outbreak was treated not as an immediate threat to the operation of public transport, but was instead used to verify the validity of transport policies, including the concept of SUMP and sustainable mobility (Kamargianni et al., 2022). Nevertheless, the authorities' recommendations for using public transportation during the pandemic varied. For example, authorities in Cracow, Paris, Milan, Vancouver and Berlin temporarily replaced car lanes with bike lanes and pedestrian facilities. As a result, and due to the need to maintain social distance, many people changed their mode of travel (to walking or biking). Restrictions imposed by governments on occupancy limits on public transportation meant that, despite the decline in passenger numbers, real demand for public transportation increased. For example, the Dutch government suggested using public transportation only when really necessary, bypassing rush hours. In Poland, a limit of 50% occupied seats in public transport vehicles was introduced at the end of March 2020 and lasted until February 2021 – with the possibility of extension (Bryniarska, Kuza, 2021: 3–18). Also, many cities in France, Denmark, Belgium, Finland, Luxembourg, Spain or the Netherlands with SUMPs were able to quickly and effectively adapt their mobility strategies, highlighting the resilience of the concept (Tsvetkova et al., 2022; European Commission, 2023). For example, Luxembourg, the country with the highest growth in green mobility development between 2019 and 2020, also saw an increase in the share of transport employment in total employment (reaching

10%) and an above-average increase in the share of low-emission vehicles in the number of newly registered passenger cars (an increase of more than 206%, against an EU average increase of 71%). The goal of the state's transportation policy was to make the passenger transportation system more flexible by 2020, but not by eliminating the passenger car as a means of mobility but by strengthening (developing) other forms and services of transportation, such as public transportation or on-demand buses (Portail Transpotrs, 2023). Luxembourg's actions, taking into account the idea of sustainability, also focused on supporting the renewal of the fleet through the purchase of electric and hybrid buses, zero-emission vehicles (using economic and non-economic tools), as well as the development of electric vehicle charging points (Burzyński et al., 2021). Moreover, as of March 1, 2020, all forms of public transportation in the country are free (Mobilite Gratuite, 2020). The increase in green mobility in the era of the COVID–19 pandemic in Luxembourg and other EU countries was also influenced by the decrease in demand for all energy sources, which mainly contributed to the reduction of CO_2 emissions. The fuel sector was particularly affected by the introduced restrictions (a large proportion of people stayed at home). In April 2020, consumption of road transport fuels (petrol, diesel) in Europe fell by an average of 14.6% in 2020 relative to 2019 (the smallest decline was recorded in Sweden and Finland – of 2.6%, and the largest in Poland – of 21.5%). A decline in natural gas consumption was also already observed from the beginning of 2020, due to a relatively 'warm winter' and an increase in the use of RES (Nicolini et al., 2022).

The results of the study carried out in this paper also indicate that there is a significant occurrence of differentiation and spatial polarisation in the level of development of sustainable mobility in Europe. The reasons for the differentiation can be sought in regional peculiarities, in the differently implemented models of the transport system, and in the pace of implementation of the guidelines and initiatives contained in the programme documents of EU transport policy. It is also important to better integrate different modes of transportation as a way to improve the overall efficiency of the system also through the use of innovative technologies related to sustainability. In its 2021 *Communication on the New EU Urban Mobility Framework*, the EC proposed up-to-date solutions to support the key goal of mitigating the negative impact that transport has on the environment by implementing transport plans and strategies to increase the share of public and mass transport, foster shared mobility and promote walking and cycling. Nevertheless, in many countries, the problems of urban transportation identified as early as the 1990s (e.g.: quality or accessibility of infrastructure) are still unresolved (Mężyk, Zamkowska, 2017). For example, Poland, Latvia and Romania have a higher-than-average risk of road accidents than the EU (between 2011 and 2020, the number of road fatalities, including drivers and passengers of motor vehicles and bicycles and pedestrians, averages 8.3 in Poland and Latvia, and 9.6 in Romania per 100,000 inhabitants). Moreover, Poland, Italy and France are characterised by three times the number of years of life lost due to PM2.5 exposure than the EU average. Lithuania, Estonia, Latvia and Poland are also characterised, on average, by higher levels of CO_2 emissions generated by newly registered passenger cars (above 132 tons per number of kilometres driven). The European Union has identified factors playing a significant role in the number of fatal traffic accidents, the significant contribution of automobile transport to air pollutant emissions, and the growing number of years of life lost due to PM2.5 exposure. The recurring and most significant ones include, among others, the dynamic increase in the number of passenger cars, the age of vehicles in use, the poor technical condition and lack of adequate road infrastructure, as well as the traffic habits of the public (too frequent use of passenger cars), and the prevalence of urban planning and infrastructural solutions favouring automobile transportation at the expense of public transportation (Jurgielewicz-Delegacz, 2021). A study conducted by the World Bank (Logistics Performance Indicator, LPI) covering infrastructure quality, vehicle safety, driver behaviour and emergency response shows that Romania, Bulgaria, Lithuania, Latvia, Poland and Estonia had the lowest urban transportation infrastructure performance from 2012 to 2018, while Germany, Belgium, Sweden, the Netherlands and Luxembourg had the highest (World Bank, 2023). Moreover, the competitiveness of public passenger transport, especially in Central and Eastern European countries, is also insufficient and the utilisation rate of urban public transport is low (reaching 16%) and depends mainly on the level of economic development of the country. For example, Hungary, Lithuania, the Czech Republic and Romania are among the countries with the highest public transportation efficiency, while France and the Netherlands are examples of countries with the lowest public transportation efficiency. In contrast, users in the Czech Republic, Austria and Estonia are most satisfied with the comfort, reliability and safety as well as amenities of public transportation, while Bulgaria, Italy and Greece have the highest number of people least satisfied with public transportation services (Poliak et al., 2017; Gascon et al., 2020; Minelgaitė, Dagiliūtė, Liobikienė, 2020). Moreover, in richer EU countries, greater affordability of passenger cars, lower travel costs, and growing mobility needs along with limitations of public transport offerings are leading to an increase in the number of owned vehicles and weakening the role of public transport in passenger services. The literature also indicates that carsharing, for example, is popular only in European cities with a high level of education or the presence of universities, e.g.: in France, Italy and Germany, and less popular in cities where many people commute by car, e.g.: in Sweden or Poland (Münzel et al., 2019). There is also a growing interest in developing smart and low-carbon urban mobility in an increasing number of European cities, especially in the areas of introducing strategies, developing plans and investing in transportation solutions. However, the effectiveness and scale of implementation of transportation plans and strategies varies regionally. For example, in the case of SUMPs, a total of 1,000 adopted SUMP programmes were identified in 2017 (there was an increase of 200 SUMP initiatives compared to 2013 with significant contributions from Romania, Slovenia and Sweden). Moreover, in fact, two regions (Flanders in Belgium and Catalonia in Spain), France, Norway and Latvia account for half the number of SUMPs adopted in Europe. The lowest utilisation rates were recorded in Estonia, Ireland, Latvia and Poland (Durlin, 2018).

The results of the assessment show Belgium, Sweden and Hungary as the countries with the highest level and most dynamic development of green transport (a high value of the composite index). Luxembourg, Lithuania, Portugal, Estonia and Poland alternated last places in the compiled ranking. Hence, it follows that the commitment of individual EU Member States to the goals and financing of investments related to sustainable urban mobility systems varies and needs to be strengthened through reliable information, incentives, guidance, as well as substantive and financial assistance (Klímová, Pinho, 2020; Motowidlak, 2020). Belgium's high ranking results from the highest number of rail passengers among the countries surveyed (10,216 per 1 million inhabitants compared to an average of 693) and distinctively lower CO_2 emissions from newly registered passenger cars (119 tons per number of kilometres driven with the EU average of 124 tons). In Brussels, for example, the underground and tramways use 100% green electricity and emit no pollution locally. The city's public transport operator (STIB) has embarked on an energy transition through the purchase of new electric and hybrid buses, and by 2035 the entire bus network is to be replaced with electric. In Brussels, technologies are also being introduced to recover energy from the train entering the station to power other infrastructure (escalators, lifts, waiting time indicators, etc.) In addition, four pollution concentration thresholds have been established in the city, and information is provided to the public on the extent to which acceptable pollution levels are exceeded. If the concentration exceeds the last threshold, then, with the exception of certain vehicles, vehicular traffic is banned in designated areas of the city, and public city transportation on a given day becomes free of charge (CORE, 2023). The 'Secure Drive' programme (a system for a greener driving mode based on reducing the maximum allowed speed and controlling driving) has also been implemented in selected regions of Belgium. The goal of the project is to reduce emissions, lower fuel consumption and provide greater comfort for travellers (STIB, 2023). In 2020, the Belgian government also approved a Regional Mobility Plan for the Brussels Capital Region called 'Good Move.' The plan aims to improve the living conditions of residents by reducing the number of cars in cities and making space available for people on foot and on unicycles. The plan also includes the popularisation of public transportation (Brussels Regional Public Service, 2023). Sweden was also among the identified leaders in the development of green transport in the EU. The country had the lowest average level of greenhouse gas emissions in the entire transport sector (1.7 tons per capita vs. an average of 8.3 tons in the group of countries surveyed) and the highest share of renewable energy consumption in transport in gross final energy consumption (22.7% vs. 6.5%). For example, the process of transforming the transportation sector to one that is greener, uses renewable energy sources and is based on the concept of sustainability began in Stockholm as early as the 1980s. The city's public transport system, thanks to a long-term approach, thoughtful solutions and clearly defined milestones, was already using 100% renewable energy in the underground, buses and local trains in 2017. Moreover, most facilities, depots and bus stops are heated with green energy. New construction work is subject to strict recycling and eco-labelling requirements, and public transportation throughout Sweden operates in a way to ensure that all services emit less noise, minimise air emissions and meet the needs of residents (Smart City Sweden, 2023). In 2021, a list of ten ways leading to a greener future was published in Scandinavia – two of which referred to green transportation solutions through the use of electric buses in urban transportation and so-called smart roads. In addition to Stockholm's transportation system, several other cities across Sweden have introduced zero-emission electric buses. One of these is Gothenburg, which began using electric bus lines earlier (in 2015) than Stockholm. By 2021, 145 such new buses were already running along the city's streets. In addition, as part of the 'ElectriCity' initiative, Gothenburg is also testing geofencing, a system that allows access to all vehicle data which is connected to the Internet. In special zones where the vehicle is connected to the grid, the technology enables digital control of speed, emissions, and location access. Another pioneering solution involves a smart road that allows electric vehicles to charge in traffic. A 2-kilometre stretch of road has been built on the outskirts of Stockholm, which is equipped with special charging rails for electric vehicles (mainly lorries and buses). The Swedish government plans to rebuild the country's busiest roads so that they can be electrified by 2030. And in 2016, the world's first electric section of public road was inaugurated on the motorway between the Swedish cities of Gävle and Sandviken (Swedish Institute, 2023). Hungary, on the other hand, is characterised by the highest average share of passenger transport by train and bus (about 30%, with an average of about 18%) and a relatively small share of passenger car transport in total ground passenger transport work (it is about 60%, in contrast to the average for the rest of the EU countries, where the share is between 80% and 90%). Such a favourable situation for Hungary (in terms of sustainable mobility) can also be explained by the historical context, which determines the lower rate of motorisation due to the country's worse economic situation (in contrast to other post-communist countries in Eastern Europe) and the important role of the public transport network (99.9% of the country's towns and cities are well connected by public transport) (Oszter, 2017). In 2019, the Hungarian government launched the 'Green Bus' programme, which aims to protect the climate and the environment by subsidising modern, sustainable and environmentally friendly public transportation. The programme will provide cities with more than 25,000 residents and their transport companies with €101 million for the purchase of electric buses between 2020 and 2029. As part of a pilot programme previously launched in the cities of Debrecen, Bekescsaba and Nyiregyhaza, electric buses will run in eight cities. So far, they have covered an average of 165 kilometres a day, and their operation has been cheaper than traditional buses by 76 cents per kilometre. In addition, they emit 4,500 kg less carbon dioxide per month, an annual reduction of 50,000 kg per bus (Ceenergy News, 2020). Luxembourg (which recorded the highest relative growth in the green transport development measure in 2019–2020, but which also ranked last in the surveyed countries) is a country characterised, among others, by a diverse population density, a rapidly growing population and a small area – along with Malta, it is among the smallest EU countries (Statec, 2023). The factors outlined affect both the level and variation of demand for transportation services and the direction of development of this system. According to the data, Luxembourg also has the highest greenhouse gas emissions of the entire transportation sector among the countries studied (an average of 21 tons per capita against an average of 8.3 tons), the highest number of passenger cars-personal motorisation (7 per 100,000 inhabitants vs. 4.6), and the lowest share of employment in the transportation sector (4% vs. 5.6%). Luxembourg is a country where, due to its cross-border location, some passenger cars may only be registered but used in another country. On the one hand, the increase in the rate of motorisation is accompanied by a decline in the number of people who attempt to obtain a driver's license (a trend that has been observed since 2010). In 2018, the number of new driver's licenses issued exceeded 6,000, while in 2012 it was about 7,400 (Statec, 2023), on the other hand, the state has a high share (about 60%) of passenger car trips with a distance of up to 1 km (Kwarciński, 2018: 97–105). By 2020, a 25% share of servicing residents' transportation needs by public transportation was assumed, with the 2011 figure at 17% and the final 2020 figure at around 14% (Luxembourg National Railway Company, 2017).

7. Conclusions

The paper attempts to quantify and assess the degree of development of sustainable urban mobility in 25 European Union countries. The study was based on the key measures of sustainable mobility selected on the basis of the literature and formal criteria, so that a comparative analysis could be carried out at the selected level of aggregation. The use of Hellwig's dynamic taxonomic method allowed us to conduct a multidimensional assessment of the level of green transport development including the scale of differentiation, trends and changes in the development of the phenomenon that occurred in the countries studied from 2011 to 2020. Development leaders were also identified and countries with similar levels of green urban mobility were grouped together.

A strong group of countries characterised by a high level of sustainable mobility development, including the Scandinavian countries, Belgium (the clear leader), Hungary, Austria, Denmark, and the Czech Republic, has been identified. Nevertheless, the results of analyses conducted (including spatial autocorrelation analyses) indicate a significant and growing polarisation of countries in terms of the phenomenon (the rate of decline in the minimum values of the measure was 0.4 percentage points more dynamic than in the case of the maximum values of the measure, i.e.; $y_{min} = -0.5\%$ vs. $y_{max} = -0.1\%$). Despite the spatial polarisation of development, a certain structural similarity characterises the countries belonging to the group with the highest and lowest levels of sustainable mobility development.

Analysing the values of the measure over the entire time series (i.e., 2011–2020), one can observe a decline in the level of development in the sustainable transportation sector. The downward trend was mainly caused by the changes that occurred in the years 2011–2014, which was dictated by the effects of the financial crisis initiated in 2007 in the US. In contrast, the years 2015–2020 saw a dynamisation of the development of green areas of the transportation industry. Moreover, the years 2019–2020 (the first years of the pandemic) also saw an increase in the level of green mobility.

Analysing the determinants of green urban mobility, it can be noted that despite the efforts made, European transport policy still faces many sustainability challenges, especially due to the steady increase in greenhouse gas emissions from the transport sector. In addition, regional peculiarities and differences in transportation models run the risk of undermining the results of the European Union's efforts, which also serve to achieve the Green Deal's climate goals. In Western European and Scandinavian cities, the process of improving transportation systems has been underway for many years. This makes it more effective, efficient, people- and economy-friendly. In these countries, the right solutions were not introduced in a sudden and ill-considered manner, and therefore the technical infrastructure is more sustainable (its quality is also rated higher), and smart transportation solutions are examples that other countries follow. In Eastern European cities, on the other hand, due to the huge scale of degradation resulting from decades of neglect, there should be almost complete reconstruction of the transportation infrastructure. However, this is practically impossible to do in the short term and much more difficult than the systematic improvement of infrastructure. The main reason is related to the internal costs associated with the renovation of technical infrastructure, the purchase of electric or low-emission modes of transport, and the external costs of transport generated by greenhouse gas emissions, air pollution, congestion, bottlenecks, accidents, and noise. The modernisation process also requires professional preparation of organisational, technical and economic scenarios for actions to be undertaken over many years. All studies must be based on proven methods so as not to lead to further delays in the development. In addition to the aforementioned problems, there is also a need to gain public trust and raise public awareness. It is also crucial that city governments be supported by the legislative and executive branches of the state, so that any changes and actions can be implemented under the same laws and with equal development opportunities for every region of the country. Once green solutions are in place, improved infrastructure and new fleet should make public transportation services more reliable, regular, frequent, and responsive to residents' needs.

In the course of the literature research, it also became clear that the creation of a single, valid system for quantifying sustainable transportation, and thus measuring the development of green transportation, as well as creating parameters for this assessment, is a difficult task. Among other reasons, this is due to the lack of a clearly defined set of monitoring indicators and the difficulty of obtaining a consistent, complete set of statistical information. On the other hand, this means that the choice of indicators is not limited by the already available standard or existing set of indicators. So far, researchers have focused on transport systems and mobility mainly from the point of view of impact on the natural environment, taking into account to a lesser extent the quality of life of residents and economic aspects such as prices of services and the competitiveness of public transport prices compared to individual motorisation. Additionally, very few studies have taken into account the diverse economic, geographic and demographic situation of individuals. This may prove how difficult it is to obtain data from various fields for analysis. Therefore, the proposal for an aggregate approach to the development of sustainable transport presented in this paper is an attempt at an innovative, comprehensive approach to assessing the degree of 'greening' of urban mobility based on available public data in the EU. The constructed measure and assessment of the level of green mobility is a research proposal that can provide important and high-quality information about changes in the quality and attractiveness of services in the green transport sector. The obtained conclusions may be valuable for national authorities.

In turn, expanding (developing) a system of indicators, including combining elements and linking them into categories or disaggregating measures into lower levels of spatial reference, will be a direction for further research, resulting in the acquisition of information providing many opportunities for evaluating the goals of transport policies or assessing modal changes (towards more environmentally friendly modes of transport) for local governments at various levels of administration.

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Kwantyfikacja i analiza rozwoju zrównoważonej mobilności miejskiej w wybranych krajach UE z wykorzystaniem miary agregatowej

Streszczenie: W artykule dokonano kwantyfikacji i oceny stopnia rozwoju zrównoważonej (zielonej) mobilności miejskiej w wybranych krajach Unii Europejskiej. W tym celu skonstruowano kluczowe wskaźniki opisujące poszczególne obszary zielonego transportu w latach 2011–2020. W analizie wykorzystano dostępne dane publiczne i zastosowano dynamiczną taksonomiczną metodę Hellwiga. Wyniki analizy umożliwiły uzyskanie odpowiedzi na postawione pytania badawcze: 1) „Jaki jest stan i dynamika rozwoju zielonego transportu w badanych państwach?", 2) „Które państwa w UE są liderami zrównoważonego transportu i dlaczego?", 3) „Co determinuje zróżnicowanie i rozwój zielonej mobilności miejskiej w analizowanych krajach?". Rezultaty badania wskazały, że pomimo przestrzennej polaryzacji rozwoju występuje podobieństwo strukturalne cechujące kraje o najwyższym i najniższym poziomie rozwoju zrównoważonej mobilności. Silną grupę stanowią państwa skandynawskie, Belgia (zdecydowany lider), Węgry, Austria, Dania i Czechy. W latach 2011–2020 można zaobserwować spadek poziomu rozwoju w sektorze zrównoważonego transportu, determinowany m.in. skutkami globalnego kryzysu finansowego w latach 2011–2014. Z kolei lata 2015–2020 to dynamizacja rozwoju ekologicznej branży transportu. Analizując czynniki warunkujące ten rozwój, można zauważyć, że pomimo podjętych starań europejska polityka transportowa nadal stoi w obliczu wielu wyzwań, zwłaszcza ze względu na stały wzrost poziomu emisji gazów cieplarnianych w sektorze transportu. Ponadto specyfika regionalna i różnice w modelach transportu niosą ze sobą ryzyko osłabienia wyników działań Unii Europejskiej w tym obszarze.

Słowa kluczowe: rozwój zrównoważonego transportu, miejska mobilność, wskaźniki zielonego transportu, zróżnicowanie regionalne, kraje Unii Europejskiej, miara agregatowa

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