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Assessment of the Transport System in the European Union Countries in a Dynamic Approach

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Abstract:

Purpose: *The aim of this article is to analyse the impact of the development of the transport system in European Union countries on the level of security in dynamic terms.*
Design/Methodology/Approach: *A multi-criteria method was used in the analysis. In this context, the article attempts to identify the main indicators reflecting changes to the level of transport safety. The analysis temporally covers the period from 2012 to 2024. During the period studied, the development of the transport system was evident, particularly in the Central and Eastern European countries. Development in these countries was facilitated by aid funds from the European Union. The development of the transport system affected all modes of transport, although most investments were made in road transport. On the other hand, road transport is also a branch of transport in which a high number of road accidents still occur.*
Findings: *The article is theoretical and empirical in nature. The theoretical layer presents an overview of the scientific literature on the transport system as a tool influencing safety levels. The literature review pays particular attention to transport infrastructure and Intelligent Transport Systems (ITS). The practical part presents the effects of the post-2012 security changes in the European Union.*
Practical implications: *The development of the transport system has led to changes in transport. Changes have included improvements in the level of safety in transport.*
Originality: *There is a lack of studies in the literature presenting the impact of transport system changes on the level of safety in dynamic terms. The value of the article is the use of a multi-criteria method.*

Keywords: *Transport system, safety, multi-criteria analysis.*

JEL classification: *R41, R42.*

Paper type: *Research article.*

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1. Introduction

The development of the transport system has an impact on the level of safety in terms of people and cargo moved. Development can be achieved in many ways. The basic ones include the construction of new infrastructure, the modernisation of existing infrastructure or solutions based on Intelligent Transport Systems.

One of the countries where the transport system has been intensively developed in recent years is Poland. It should be emphasised that Poland's integration with the EU has had a positive impact on the development of the transport system, particularly in the area of road transport. A valuable example in this respect is the construction of new roads and in particular motorways, motorways and roads with an improved surface. According to the Central Statistical Office (GUS), the length of motorways in Poland, increased in the years 2000-2023 by about 1500 km (from 358 km to 1851 km).

In the same period, the length of express roads in Poland increased by approximately 2,800 km (from 193 km to 3,070 km) and the length of roads with improved pavement by approximately 94,000 km (from 205,000 km to 299,000 km). The highest growth rate was recorded for motorways, which differ slightly in their parameters from motorways. The difference mainly concerns the width of the emergency lane, which is narrower on expressways. The positive impact on the safety of motorways and expressways is mainly due to the separation of traffic moving in opposite directions.

The development of road transport infrastructure as a factor in improving safety has been and continues to be important, not least in view of the rapidly increasing motorisation rate. This trend is widespread. On a European scale, it is characteristic of Central and Eastern European countries including Poland. In the period from 2000 to 2023, the motorisation index in the EU increased from 424 to 571, and in Poland from 261 to 601.

Therefore, it can be said that the scale of the increase in the motorisation index in Poland was much higher than the pan-European one. In contrast, the growth of the motorisation index in selected countries of Central and Eastern Europe in the period

2000-2022 was as follows: Romania -139;425, Croatia - 261;495, Hungary - 232;435, Slovakia - 237;486, Estonia - 333;630. In 2023, the highest motorisation rates were recorded in Italy - 694, Luxembourg - 675, Cyprus - 665 and Finland - 664 [https://ec.europa.eu]. On a European scale, the highest rate of motorisation is in Liechtenstein with 774.

In addition to quantity, the quality of the means of transport is also important and is an important factor in the level of safety in road transport. One measure reflecting the quality of transport means can be their age. It can be assumed that older vehicles, for various reasons, are less safe than new ones. In Poland, but also in other countries of Central and Eastern Europe, the average age of vehicles remains high, which is due, inter alia, to the influx of second-hand vehicles from Western Europe.

The most numerous groups of passenger cars are those whose age ranges from 16-20 years - 20%. Cars in the age group 12-25 years are about 50% (Transport wyniki, 2023).

Within the transport system, an important element that has a positive impact on safety is Intelligent Transport Systems. Its essential role is to improve traffic management. This system is particularly important for urbanised areas where it is difficult, due to limited space, to further expand the transport infrastructure (Macioszek, 2014).

The development of the road transport system has a positive impact on road safety. This is confirmed by statistics on the number of road accidents, people killed or injured in Poland. In Poland in the years 2000-2023 the number of road accidents fell from 57,000 to 20,000. In the same period the number of people killed also fell from 6,200 to 1,800 and the number of injured from 71,000 to 24,000 (Transport wyniki, 2023).

Interestingly, the majority of accidents take place in urban areas, while the number of accidents that occur in undeveloped areas is definitely more tragic. Hence, a conclusion can be drawn about speed as an important factor determining the negative effects of accidents. Undoubtedly, motorways or motorways allow vehicles to travel safely at higher speeds.

2. Literature Review

The transport system is a set of technical, organisational and economic-legal measures in their mutual functional relationship for the realisation of socio-economic economic links in a defined area. Under this definition, 3 subsystems can be distinguished, i.e. technical, economic-legal and organisational. Similar to the above, there is the classification of A. Grzelakowski (2007), who distinguishes the following subsystems: material-technical (infrastructure, means of transport, traffic control elements), economic (transport enterprises), institutional-legal (laws, regulations, institutions).

Transport infrastructure plays an important role for the proper functioning of the transport system. Transport infrastructure remains an important factor in the choice of location for economic activity or human settlement. It also ensures territorial, social and economic cohesion. Research indicates that its role is more evident when we analyse social and economic phenomena over a longer period of time (Zhang, Chang 2023).

Transport infrastructure is characterised by limited capacity. An increase in traffic beyond its capacity, generates a number of negative effects (reduced speed, loss of time, etc.) for all its users. This situation also results in higher external costs (noise, pollution). Ongoing research into the impact of transport infrastructure on socio-economic development can relate to (Kwarciński, 2018):

- time - the quantitative growth and qualitative development of transport infrastructure contributes to a reduction in travel time;
- cost - transport infrastructure improves investment attractiveness and capital productivity and contributes to technical progress;
- efficiency - the impact on the transport process and directly on the efficiency of both producers and household budgets (lower running costs of cars).

The transport system, including the transport infrastructure, has an impact on safety levels. In addition to the road surface, safety is influenced by the quality of signage (vertical and horizontal), the quality of pedestrian crossings, including the possibility of making so-called 'asylums' to improve pedestrian safety, other infrastructural devices to protect road users, and education, training for all road users.

An important role, of a disciplinary nature, is played by the system of penalties for breaking traffic regulations. In Poland, it consists of two elements: financial and point penalties. In both cases, their amount depends on the nature of the offence. Importantly, in the latter case, exceeding a certain number of points results in withdrawal of the driving licence for a specified period.

Intelligent transport systems are an important element affecting transport safety. The system provides real-time information to transport users (e.g. drivers, organisers, passengers) (Khorasani, et al., 2013). The information can also be used by the vehicles themselves, using the network. In this respect, the development of ITS is made possible by the development of ICT technologies, geographical information (e.g. GIS), weather and road condition monitoring devices (Świderski *et al*, 2016; Zółkowski *et al.*, 2016; Nguyen *et al.*, 2018). ITS is based on the Internet of Things and vehicles (Sherly, Somasundareswari, 2015).

In terms of safety, ITS has a positive impact on reducing the number of accidents and makes it possible to reduce the time it takes to reach the injured (Ostrowska, 2018). It is estimated that thanks to ITS, the arrival time of rescue teams is shorter by about 30%. Optimum use of ITS requires an adequate level of telecommunication technology development. Unfortunately, the low level, which is characteristic of medium and underdeveloped countries (Mfenjou *et al.*, 2018), is a significant barrier to reducing the number of accidents and their negative effects.

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3. Materials and Methods

This study employs the Vector Measure Construction Method (VMCM) to dynamically assess the transport systems of European Union member states. The Vector Measure Construction Method, or VMCM, is a multi-criteria method developed relatively recently. (the methodological basis was developed in 2009 by (Nermend, 2009). A detailed description of the method and its applications has been described by (Nermend, 2023).

It utilises the properties of vector calculus to create vector aggregate measures based on the definition of an inner product. This approach enables the ranking and classification of objects and the analysis of changes over time. The analysis spans the period from 2012 to 2024, using specific criteria derived from the transport section of the Eurostat database, with 2012 serving as the reference point.

Artificial patterns, including both pattern and anti-pattern objects, were calculated based on 2012 data. The primary goal of this research is to rank EU member states according to their transport systems and to examine changes in these rankings over time. The criteria for evaluation were meticulously selected from the Eurostat database's transport section, as outlined below.

x_1 – Passenger cars - per thousand inhabitants (S).
x_2 – Number of road accident fatalities by road type (D).
x_3 – Freight transport volume in relation to GDP (S).
x_4 – Passenger transport volume in relation to GDP (S).
x_5– Railway accidents by type of accident - per thousand inhabitants (D).
x_6– Rail-related suicides - per thousand inhabitants (D).
x_7 – Railway accident victims by type of accident and category of persons involved - per thousand inhabitants (D).

x_8 – Persons killed in road accidents by age, sex, and category of persons involved in the event - per thousand inhabitants (S).
x_9– Total length of railway lines on the surface by NUTS 3 (S) region.
x_{10}– Road freight transport - per thousand inhabitants (S).
x_{11}– Maritime transport of goods - per thousand inhabitants (S).

Analyzed selected countries (decision variants) were - Bulgaria (BG), Cyprus (CY), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania(RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Data referred to the year 2012-2024 and were obtained from the Eurostat database.

Austria (AT), Greece (EL), and Belgium (BE) were not included in the analysis due to a lack of data for most of the adopted criteria.

In the initial phase of the study, a set of indicators was developed using carefully selected variables. This approach ensures accurate categorization of EU countries, as comparing smaller nations to larger ones based on general variables would be challenging. The indicators created include:

- Rail accidents by type per 1,000 inhabitants,
- Suicides involving railways per 1,000 inhabitants,
- Victims of rail accidents by type and category of persons involved per 1,000 inhabitants,
- Persons killed in road accidents by age, sex, and category per 1,000 inhabitants,
- Total length of railway lines per square kilometer,
- Goods transport by road per 1,000 inhabitants, and
- Goods transport by rail per 1,000 inhabitants.

In the next stage, missing data for some indicators were supplemented by data interpolation and their extrapolation backward and forward. Spline interpolation was used for interpolation. Spline interpolation uses lower-order polynomials to interpolate within subsets of the interpolated data set.

These polynomials are called spline functions. Spline interpolation is better suited for situations where there are sudden changes in the data values in the data sequence. These changes do not affect data that are located further away from them during interpolation. Thanks to this, anomalies in indicator values will not significantly affect interpolation. Linear spline functions were used in the interpolation. They create a set of linear functions (Chapra, 2015):

$$f(x) = f(x_0) + m_0(x - x_0) \quad x_0 \le x \le x_1 \tag{1}$$

$$f(x) = f(x_1) + m_1(x - x_1) \quad x_1 \le x \le x_0$$

where $x_0, x_1, \cdots, x_{N-1}$ it's a series N points for which the function values are known$f(x)$, $f(x_0), f(x_1), \cdots, f(x_{N-1})$ – function values $f(x)$ in points $x_0, x_1, \cdots, x_{N-1}$, m_0 the data is a pattern:

$$m_i = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i} \tag{2}$$

By inserting any value from the range x_0 to x_{N-1}) as x, we can determine the missing values of the indicators. For backward extrapolation, polynomial interpolation was used using the polynomial function (Bronshtein 1985):

$$p_0(x) = c_0 + c_1 x + c_2 x^2 + \cdots + c_N x^N \tag{3}$$

Horner's method was used to determine the $c_0, c_1, \cdots, c_N$ values, Holt's method was used to extrapolate forward and remove random fluctuations. The following relations were used for this purpose (Hyndman 2018):

$$F_1 = x_1 \tag{4}$$

$$F_t = \alpha x_t + (1 - \alpha)(F_{t-1} + S_{t-1}) \tag{5}$$

$$S_1 = x_2 - x_1 \tag{6}$$

$$S_t = \beta(F_t - F_{t-1}) + (1 - \beta)S_{t-1} \tag{7}$$

where
x_t – real values for the analyzed variable$(t = 1,2, \ldots, n)$,
$\alpha \in (0;1\rangle$ – smoothing constant,
S_t – smoothed trend growth value for the period t,
$\beta \in (0;1\rangle$ – smoothing constant of the increase in the trend of the studied variable.
As a value α accepted 0,697, and as β – 1.
After supplementing the data, their scope was limited to the years 2012-2014.

The indicators were standardized using the formula (Nermend 2009):

$$x'_i = \frac{x_i - \overline{x}}{\sigma} \tag{8}$$

whre x_i are the values of the indicator, $\overline{x}$ is the average value of the indicator in 2012, and σ is the standard deviation of the indicator in 2012. When standardizing the indicators in all years, the mean value and standard deviation from 2012 were used. This was to ensure comparability of the indicator values in individual years.

The measurement values were determined using the VMCM method. For each indicator its character was determined**.** The character of criteria can be as stimulants (benefits), destimulants (no benefit), and nominatns (natural, interval). Stimulants (benefits) are such criteria in which greater values mean a higher level of benefits.

Destimulants are such criteria in which smaller values mean a higher level of benefits, while nominatns are criteria in which desired values are within a specific range. in the study, the criteria ($x_1, x_3, x_{4.....}, x_9, x_{10}, x_{11}$) had character stimulants (benefits) and (x_2, x_5, x_6, x_7, x_8) was destimulants (no benefit).

The VMCM method enables the use of patterns and anti-patterns as real-life objects, or their automatic determination based on the first and third quartiles. This study applies both approaches (Kolenda, 2006). For stimulants (beneficial values), the coordinates of the pattern correspond to the third quartile, while for destimulants (non-beneficial values), the coordinates are based on the first quartile:

$$x'_{i\,w} = \begin{cases} x'_{i_{q_{III}}} & \text{for stimulants} \\ x'_{i_{q_I}} & \text{for destimulants} \end{cases} \tag{9}$$

Where:
$x'_{i\,w}$ is the value of the i-th normalised variable for the pattern, $x'_{i_{q_I}}$ - the value of the i-the normalised variable for the first quartile, and $x'_{i_{q_{III}}}$ - the value of the i-th normalised variable for the third quartile. In the case of an anti-pattern, the procedure is inversed. Values in the first quartile are anti-pattern coordinates for stimulants, and values in the third quartile for destimulants:

$$x'_{i\,aw} = \begin{cases} x'_{i_{q_I}} & \text{for stimulants} \\ x'_{i_{q_{III}}} & \text{for destimulants} \end{cases} \tag{10}$$

where $x'_{i\,aw}$ means the value of the *i*-th normalised variable for anti-pattern.

Based on formulas 9 and 10, the pattern and anti-pattern were determined using quartiles. The pattern was determined for the year 2012 and used for calculations in all years.
The measurement values were determined from the formula (Nermend 2009):

$$m_i = \frac{\sum_{j=1}^{M}(x'_{i,j} - x_{w,j})(x_{w,i} - x_{aw,j})}{\sum_{j=1}^{M}(x_{w,j} - x_{aw,j})^2}, \tag{11}$$

where $x'_{j,i}$ is a standardized value j-th indicator for i-th object, $x_{w,j}$ – pattern value for j-th indicator, $x_{aw,j}$ – anti-pattern value for j-th indicator.

The last step of the VMCM method is decision variant rankings depending on the obtained aggregate measure values.

Thus, it is possible to determine which of them are "better" and which are "worse". They also allow determining which are like each other in terms of adopted criteria. Decision variants can be divided into classes with similar measurement values to better visualise the results of calculations. In the simplest case, objects can be classified based on mean value $\overline{m}_{m_{ao}}$ and standard deviation of the aggregate measure $\sigma_{m_{ao}}$.

Objects are classified into four classes(Nermend, 2009):

$$\begin{cases} 1 & \text{for} \quad m_{aj} \in \langle \overline{m}_{m_{ao}} + \sigma_{m_{ao}}\ ;\ \infty), \\ 2 & \text{for} \quad m_{aj} \in \langle \overline{m}_{m_{ao}}\ ;\ \overline{m}_{m_{ao}} + \sigma_{m_{ao}}), \\ 3 & \text{for} \quad m_{aj} \in \langle \overline{m}_{m_{ao}} - \sigma_{m_{ao}}\ ;\ \overline{m}_{m_{ao}}), \\ 4 & \text{for} \quad m_{aj} \in (-\infty\ ;\ \overline{m}_{m_{ao}} - \sigma_{m_{ao}}). \end{cases} \tag{1}$$

4. Research Results

The transport systems in EU countries were evaluated using the VMCM method. The findings, including aggregate measures and class affiliations, are displayed in tables.

The study covers the period from 2012 to 2024, highlighting significant ranking changes across three tables. It also analyzes the dynamics of changes in the level of transport systems within EU countries.

Aggregate measures were calculated annually, using the pattern variant based on 2012 data as the reference point. Table 1 shows the results of the classification of EU countries due to the level of transport system based on data from 2012 and 2016, many differences in-class assignments can be observed, the most important of them is Ireland changed its ranking from 2 to 5 in 2016 because the value of the criteria, the Volume of freight transport relative to GDP (X_3= 15.96%), and Volume of passenger transport relative to GDP (X_4= 19.04%) was decreased in Ireland.

The number of Persons killed in road accidents by age (X_8= 10.44%) was increased in Ireland. Germany changed its ranking from 5 to 3 in 2016. because the value of the criteria, the Road traffic deaths, by type of roads (X_2= 15.39%), the Suicides involving railways (X_6= 9.27%), and The Persons killed in road accidents by age (X_8= 10.44%), was decreased in Germany. The Goods transport by road (X_{10}= 7.07%) and the Goods transport by rail (X_{11}= 7.11%) was increased in Germany.

Table 1. *Ranking of EU countries in 2012 and 2016 respect the level of transport system VMCM method.*

Country	Measure value	Class	Country	Measure value	Class
Pattern form 2012 and Data (2012)			Pattern form 2012 and Data (2016)		
Luxembourg	0,096	1	Luxembourg	0,103	1
Ireland	0,090	1	Switzerland	0,085	2
Netherlands	0,082	1	Germany	0,083	2
Switzerland	0,081	1	Norway	0,083	2
Germany	0,078	2	Ireland	0,082	2
Norway	0,073	2	Netherlands	0,080	2
Spain	0,071	2	Spain	0,077	2
Denmark	0,070	2	Denmark	0,077	2
Italy	0,070	2	Italy	0,075	2
France	0,068	2	Finland	0,070	2
Sweden	0,063	2	France	0,069	2
Finland	0,062	2	Sweden	0,069	2
Slovenia	0,043	3	Slovenia	0,063	2
Estonia	0,041	3	Estonia	0,052	3
Portugal	0,032	3	Portugal	0,045	3
Lithuania	0,026	3	Czechia	0,044	3
Czechia	0,024	3	Lithuania	0,043	3
Poland	0,015	3	Poland	0,035	3
Bulgaria	0,005	4	Slovakia	0,020	4
Slovakia	0,002	4	Croatia	0,016	4
Croatia	-0,001	4	Latvia	0,010	4
Hungary	-0,004	4	Bulgaria	0,008	4
Latvia	-0,006	4	Hungary	0,003	4
Romania	-0,022	4	Romania	-0,003	4

Source: *Own study.*

The Netherlands changed its ranking from 3 to 6 in 2016. because the value of the criteria, the Volume of passenger transport relative to GDP (X_4= 7.88%) was decreased in the Netherlands. The Suicides involving railways (X_8= 8.60%) were increased in the Netherlands.

Norway changed its ranking from 6 to 4 in 2016. because the value of the criteria, the Road traffic deaths by type of roads (X_2= 11.54%), the Rail accidents by type of accident (X_5= 18.75%), and The Persons killed in road accidents by age (X_8= 7.41%) was decreased in Norway. The Goods transport by rail (X_{11}= 8.98%) was increased in Norway. The situation in the third and fourth classes is relatively stable. There is little change in them. Only changes which are Slovenia changed its place from class three to class two.

Table 2 shows the results of the classification of EU countries due to the level of a transport system based on data from 2012 and 2020, many differences in-class assignments can be observed, the most important of them is Ireland changed its ranking from 2 to 12 in 2020. because the value of the criteria, the Volume of freight transport relative to GDP (X_3= 69.87%), Volume of passenger transport relative to GDP (X_4= 77.11%), Goods transport by rail (X_{11}= 26.28%), the Road traffic deaths, by type of roads (X_2= 20.69%), and Persons killed in road accidents by age (X_8= 13.19%) was decreased in Ireland. Despite a 10.07% increase in the X_9 indicator (Total length of railway lines) and a 23.94% increase in the X_{10} indicator (Goods transport by road), these improvements did not significantly impact Ireland's high position in the ranking.

The Netherlands changed its ranking from 3 to 9 in 2020 because the Volume of the criteria passenger transport relative to GDP (X_4= 56.14%) decreased in the Netherlands. Despite a 50% reduction in the X_5 indicator (Rail accidents by type of accident) and a 13.33% decrease in the X_2 indicator (Road traffic deaths by type of roads), these improvements did not influence the Netherlands' ability to maintain its high position in the ranking.

Table 2. *Ranking of EU countries in 2012 and 2020 in respect of the level of transport system VMCM method.*

Country	Measure value	Class	Country	Measure value	Class
Pattern form 2012 and Data (2012)			Pattern form 2012 and Data (2020)		
Luxembourg	0,096	1	Luxembourg	0,096	1
Ireland	0,090	1	Switzerland	0,086	1
Netherlands	0,082	1	Germany	0,086	1
Switzerland	0,081	1	Spain	0,083	2
Germany	0,078	2	Norway	0,082	2
Norway	0,073	2	Italy	0,080	2
Spain	0,071	2	Denmark	0,079	2
Denmark	0,070	2	Finland	0,075	2
Italy	0,070	2	Netherlands	0,073	2
France	0,068	2	France	0,072	2
Sweden	0,063	2	Sweden	0,070	2
Finland	0,062	2	Ireland	0,067	2
Slovenia	0,043	3	Slovenia	0,065	2
Estonia	0,041	3	Lithuania	0,061	2
Portugal	0,032	3	Czechia	0,058	2
Lithuania	0,026	3	Estonia	0,056	3
Czechia	0,024	3	Portugal	0,048	3
Poland	0,015	3	Poland	0,048	3
Bulgaria	0,005	4	Slovakia	0,034	3
Slovakia	0,002	4	Croatia	0,021	4
Croatia	-0,001	4	Hungary	0,021	4
Hungary	-0,004	4	Bulgaria	0,012	4
Latvia	-0,006	4	Latvia	0,012	4
Romania	-0,022	4	Romania	0,008	4

Source: *Own study.*

Czechia moved from class 3 at position 17 to class 2, achieving position 15 in the ranking. In 2020, because of the value of the criteria Passenger cars - per thousand inhabitants (X_1= 22.22 %), the Volume of freight transport relative to GDP (X_3= 18.48%), and the goods transport by road (X_{10}= 26.19%) was increased in Czechia. While the value of the criteria of the Road traffic deaths, by type of roads (X_2= 47.92%) and Persons killed in road accidents by age (X_8= 43.24%) was decreased in Czechia.

Table 3 shows the results of the classification of EU countries due to the level of a transport system based on data from 2012 and 2022, many differences in class assignments can be observed, the most important of them is Ireland moved from class 1 to position 2 to class 3, achieving position 15 in the ranking in 2022, because of the value of the criteria, the Volume of freight transport relative to GDP (X_3= 91.79%), Volume of passenger transport relative to GDP (X_4= 90.17%), Goods transport by rail (X_{11}= 35.32%), was decreased in Ireland.

Lithuania moved from class 3 at position 16 to class 2, achieving position 10 in the ranking in 2022, because of the value of the criteria, Road traffic deaths, by type of roads (X_2= 140.48%), Rail accidents by type of accident (X_5= 271.43%), Suicides involving railways (X_6= 116.67%), Rail accidents victims by type of accident and category of persons involved (X_7= 375%) and Persons killed in road accidents by age (X_8= 151.67%) was decreased in Lithuania.

Table 3 presents the ranking of EU countries in 2012 and 2022 in respect of the level of transport system VMCM Spain moved from class 2 at position 7 to class 1, achieving position 2 in the ranking in 2020, because of the value of the criteria Suicides involving railways (X_6= 58.62%) and Rail accidents victims by type of accident and category of persons involved (X_7= 28,57%) was decreased in Spain in 2022. The value of the criteria Total length of railway lines (X_9= 28,57%), and Goods transport by road (X_{10}= 28,57%) was increased in Spain in 2022.

Table 3. *Ranking of EU countries in 2023 and 2024 in respect of the level of transport system VMCM method.*

Country	Measure value	Class	Country	Measure value	Class
Pattern form 2012 and Data (2012)			Pattern form 2012 and Data (2022)		
Luxembourg	0,096	1	Luxembourg	0,087	1
Ireland	0,090	1	Spain	0,086	1
Netherlands	0,082	1	Switzerland	0,086	1
Switzerland	0,081	1	Germany	0,086	1
Germany	0,078	2	Italy	0,082	2
Norway	0,073	2	Norway	0,078	2
Spain	0,071	2	Denmark	0,078	2
Denmark	0,070	2	Finland	0,077	2
Italy	0,070	2	France	0,074	2
France	0,068	2	Lithuania	0,071	2

Sweden	0,063	2	Sweden	0,069	2
Finland	0,062	2	Netherlands	0,066	2
Slovenia	0,043	3	Czechia	0,064	2
Estonia	0,041	3	Slovenia	0,059	2
Portugal	0,032	3	Ireland	0,058	3
Lithuania	0,026	3	Estonia	0,055	3
Czechia	0,024	3	Poland	0,052	3
Poland	0,015	3	Portugal	0,046	3
Bulgaria	0,005	4	Slovakia	0,039	3
Slovakia	0,002	4	Hungary	0,033	3
Croatia	-0,001	4	Croatia	0,020	4
Hungary	-0,004	4	Bulgaria	0,015	4
Latvia	-0,006	4	Romania	0,011	4
Romania	-0,022	4	Latvia	0,008	4

Source: *Own study.*

Italy moved from position 9 to position 5 in the ranking in 2022, because of the value of the criteria the Road traffic deaths, by type of roads (X_2= 14.81%) and Persons killed in road accidents by age (X_8= 43.24%) was decreased in Italy in 2022. The value of the criteria freight transport relative to GDP (X_3= 14.06%), and Goods transport by rail (X_{11}= 15.34%), was increased in Italy in 2022.

Czechia moved from class 3 at position 17 to class 2, achieving position 13 in the ranking in 2022, because of the value of the criteria Passenger cars - per thousand inhabitants (X_1= 23.02 %), the Volume of freight transport relative to GDP (X_3= 21.78%), and the goods transport by road (X_{10}= 28.37%) was increased in Czechia. While the value of the criteria of the Road traffic deaths, by type of roads (X_2= 44.90%) was 3.02% worse compared to 2020, and Persons killed in road accidents by age (X_8= 40.80 %) was 2,44 % worse compared to 2020, was decreased in Czechia in 2022.

The data presented in Table 4 are forecasted based on previous years. The situation in the fourth class remains relatively stable during 2023-2024. In the third class, Poland rose to become the leader in 2024. Class one consists of four countries: Spain, Switzerland, Germany, and Italy, which demonstrate effective policies for the transport system within the EU.

Lithuania's situation has improved a lot compared to 2012 because it was in the third class, in 2024 it is in the 2nd class.

Table 4. *Ranking of EU countries in 2023 and 2024 in respect of the level of transport system VMCM method.*

Country	Measure value	Class	Country	Measure value	Class
Pattern form 2012 and Data (2023)			Pattern form 2012 and Data (2024)		
Spain	0,088	1	Spain	0,090	1

Switzerland	0,086	1	Switzerland	0,086	1
Germany	0,086	1	Germany	0,086	1
Italy	0,083	2	Italy	0,084	1
Luxembourg	0,083	2	Lithuania	0,080	2
Denmark	0,078	2	Finland	0,078	2
Finland	0,078	2	Luxembourg	0,078	2
Norway	0,076	2	Denmark	0,077	2
Lithuania	0,076	2	France	0,075	2
France	0,074	2	Norway	0,074	2
Sweden	0,068	2	Czechia	0,069	2
Czechia	0,067	2	Sweden	0,067	2
Netherlands	0,063	2	Netherlands	0,060	2
Slovenia	0,057	3	Poland	0,056	3
Estonia	0,055	3	Estonia	0,055	3
Poland	0,054	3	Slovenia	0,053	3
Ireland	0,053	3	Ireland	0,048	3
Portugal	0,044	3	Hungary	0,046	3
Slovakia	0,041	3	Slovakia	0,043	3
Hungary	0,040	3	Portugal	0,043	3
Croatia	0,019	4	Croatia	0,018	4
Bulgaria	0,016	4	Bulgaria	0,017	4
Romania	0,012	4	Romania	0,014	4
Latvia	0,006	4	Latvia	0,003	4

Source: *Own study.*

5. Conclusions

The approach outlined in the study is highly innovative, utilizing multi-criteria methods to assess changes in the transport systems across various EU countries. The use of the VMCM method stands out, as it takes into account a wide range of socio-economic factors that could influence the transport systems in the selected countries. It's particularly compelling to see how such an approach can provide valuable insights into complex, dynamic phenomena.

The research findings reveal significant variations in the transport systems of the European countries studied. Each year, the overall performance measure was categorized into four distinct classes. Between 2012 and 2024, Luxembourg consistently ranked as the top performer, with its transport system leading the rankings from 2012 to 2022.

During the period covered by the study, Romania, Bulgaria, Latvia, and Hungary were found to have the least developed transport systems in the European Union. The transport system in Poland exhibited steady, balanced development throughout the period from 2012 to 2024, with only minimal fluctuations, all of which remained within the third-class category.

It can be concluded that development in Poland is sustainable. The road safety situation in Lithuania has developed very dynamically during this period, which may have a very positive impact on the development of the transport system in this country.

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