# Statistical Analysis of the Impact of Application of the European Union Rules on the Number of Death from Traffic Accidents and the CO Pollution

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**Abstract**

*In the context of introducing the latest rules for traffic monitoring, new types of cars propulsion, and security systems, a significant change in the trends of human life lost in car accidents and diminishing CO pollution are expected. In this article, we emphasize the trend in these two directions in the European countries. It is shown that the human loss significantly diminished in a certain number of countries, while the CO recorded a decreasing trend in 25 countries (out of 28) during the analyzed period. Clustering emphasizes the existence of the dissimilarities among the series contained in different groups obtained based on the two study criteria.*

**Key words:** trend, cluster, statistical analysis
**J.E.L. classification:** Q52, R11

## 1. Introduction

On the European Union (EUR-Lex 1) site, it is mentioned that the policy in the transport field should have as the final goal ensuring '*smooth, efficient, safe, and free movement of people and goods throughout the EU*' by all modalities and employing interconnected transportation networks.

The EU White Paper (COM(2011) 144 final) presents transportation as a key element for society and the economy that must ensure the necessities of the market and the citizens' mobility. Therefore, it must fulfill sustainability and security conditions, including pollution reduction, environment conservation and restoration, passengers' rights.

The study presented here investigates the results of EU directives implementation in the national legislation. Two time series are investigated, one reflecting the traveling security, and the second one, the pollution level with CO. The correlation of these aspects, reflected by clustering the countries based on two criteria, is finally emphasized.

## 2. Literature review

One of the critical concerns constantly raised by scientists after 2000 is pollution (Al-Taani et al., 2021; Bărbulescu and Dani, 2019; Bărbulescu and Nazzal, 2021; Nazzal *et al*., 2021a,b; Bărbulescu *et al.,* 2018, 2021)**.** WHOs reports show that over four-fifths of the urban population is affected by pollution at an alarming level surpassing the international recommendations. In the Asian and Mediterranean cities from middle and low-income countries, pollution values are 5-10 times above the warning limits (WHO, 2016a,b).

Owusu and Sarkodie (2020) showed that the WHO Directives for air quality were met by no country studied (195) in 1990 – 2017.

The Report of the European Union emphasized the necessity of drastically decreasing the pollutants emissions to limit the global temperature increase to a level under 2ºC. The EU established the target of reducing the emissions of greenhouse gases (GHGs) by 2050 under the 1990's level

(COM(2011) 144 final). The analysis of the European Commission emphasized that diminishing the GHGs emission from the transport sector by a minimum of 60% by comparison to 1990 is mandatory by 2020 (COM(2011) 112 final) given that the pollution coming from this sector is still significant. The goal set for 2030 is reaching a level 20% lower than in 2008.

On the other hand, the Directive 2010/40/EU introduced the framework for the European Union countries for the Intelligent Transport Systems deployment (EUR - Lex 2). It stipulates the implementation and application of the new communication technologies for improving the efficiency and safety of the transport and passengers.

Since the European countries transposed in their legislations the stipulations of the EU Directive, our study comes to analyze the progress of applying these regulations in two directions: reducing the pollution with CO (that is mainly due to the engine's exhaust) and diminishing the number of dead people in car accidents (that should be the direct result of the intelligent driving systems implementation and traffic monitoring).

## 3. Research methodology

Statistical analysis has been performed on the series recorded in each country (spatial analysis) aiming to emphasize the series evolution. They included:

- Computation of basic statistics and boxplot drawing for the outliers' detection.
- Testing the null hypothesis ($H_0$) that the series presents no monotonic trend versus the alternative hypothesis ($H_1$) that such a trend exists, utilizing the Mann-Kendall test (Hipel, 1994).
  If $H_0$ was rejected, the nonparametric procedure of Sen (1968) was utilized to compute the slope of the linear trend detected.
- If there is a trend, it can be increasing (when a positive significant was estimated), or decreasing (when a negative significant slope was computed).
- Testing the hypothesis ($H_0$) that the series is stationary in level/trend versus ($H_1$) its non-stationarity in level/trend, utilizing the KPSS test (Kwiatkowski et al., 1992).

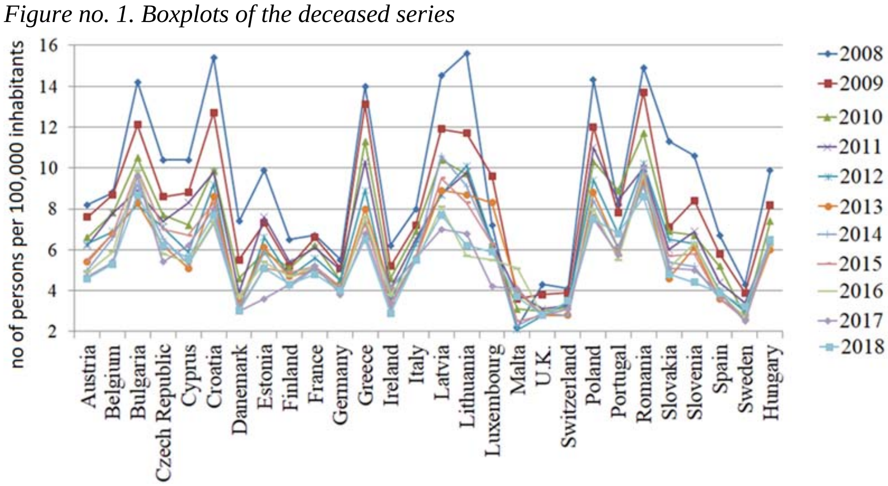
The significance level at which the hypotheses testing was done is 5%.

The series have been grouped in clusters using the k-means algorithm (Everitt et al., 2011; Xu and Wunsch, 2005).

For selecting the best number of clusters, 30 criteria have been utilized. The optimum number of clusters was selected based on the majority rule (Kassambara).

Data series consists of the annual series formed by the number of deaths in car accidents and the series of CO emissions recorded in 28 European countries in the period 2007 – 2017. Data was downloaded from Eurostat (Eurostat). The first series is represented in Figure 1.

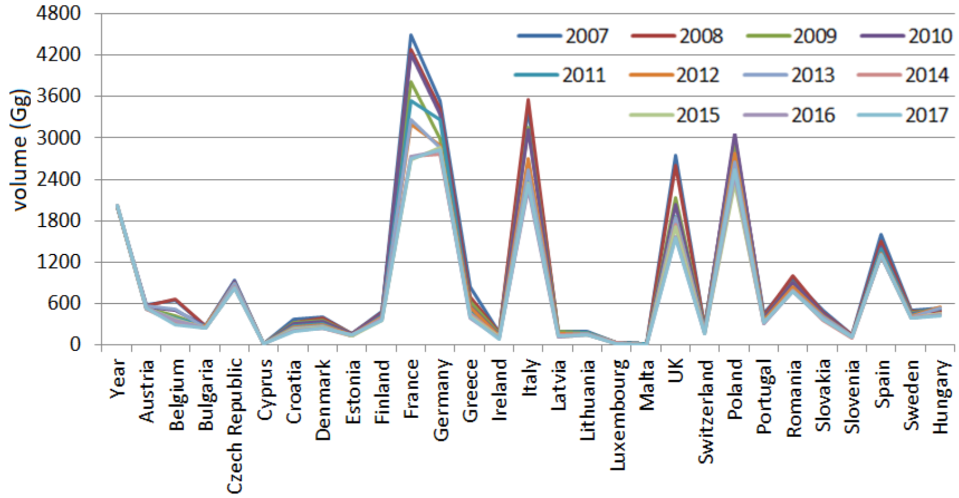
*Figure no. 1. Boxplots of the deceased series*




*Source:* Own chart drawn using data from
https://ec.europa.eu/eurostat/databrowser/view/ sdg_11_40/default/table?lang=en

Figure 2 contains the chart of average pollution with CO in the European countries during the study period.

*Figure no. 2. CO volume recorded in the European countries during the period 2007 -2017*




*Source:* Own chart drawn using data from https://ec.europa.eu/eurostat/web/main/data/database

## 4. Findings

### 4.1. Results on the deceased series

The basic statistics are presented in Table 1. The highest minimum values are reported in Romania, Croatia, Poland, Bulgaria. The highest maximum values are reported in Lithuania, Croatia, Romania, Poland, and the highest average are in Romania, Bulgaria, Latvia, and Poland. These are countries where the transportation infrastructure is deficient.

At the opposite pole, the lowest maxima were recorded in Ireland, Switzerland, Sweden, Germany. In contrast, the lowest average was registered by Sweden, U.K., Switzerland, and Malta, where the legislation is less permissive to the traffic rules violations.

The coefficient of variation (cv) (Table 1) indicates the highest variation of the series values for Denmark, Slovakia, Lithuania, and Malta. The first three mentioned series exhibit a decreasing trend, based on the results from Table 2.

*Table no. 1. Basic statistics of the deceased series*

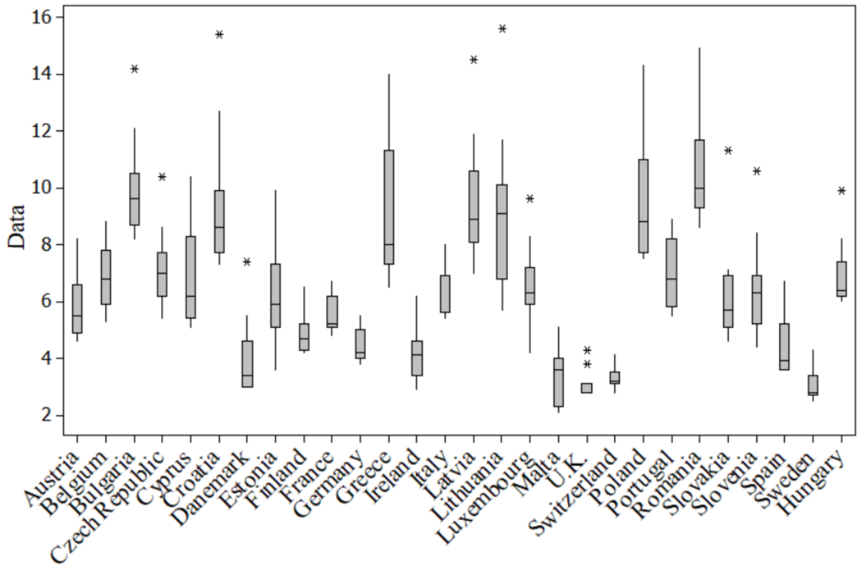
| | Austria | Belgium | Bulgaria | Czech Republic | Cyprus | Croatia | Denmark | Estonia | Finland | France | Germany | Greece | Ireland | Italy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| min | 4.6 | 5.3 | 8.2 | 5.4 | 5.1 | 7.3 | 3.0 | 3.6 | 4.2 | 4.8 | 3.8 | 6.5 | 2.9 | 5.4 |
| max | 8.2 | 8.8 | 14.2 | 10.4 | 10.4 | 15.4 | 7.4 | 9.9 | 6.5 | 6.7 | 5.5 | 14.0 | 6.0 | 8.0 |
| mean | 5.9 | 7.0 | 10.0 | 7.1 | 6.1 | 9.5 | 4.0 | 6.2 | 4.9 | 5.6 | 4.4 | 9.2 | 4.1 | 6.2 |
| St.dev | 1.2 | 1.2 | 1.8 | 1.4 | 1.7 | 2.5 | 1.4 | 1.6 | 0.7 | 0.7 | 0.6 | 2.6 | 0.9 | 0.9 |
| cv(%) | 20.2 | 17.1 | 18.0 | 19.9 | 25.1 | 26.3 | 34.7 | 26.4 | 13.3 | 12.0 | 12.4 | 28.4 | 23.2 | 13.9 |

| | Latvia | Lithuania | Luxembourg | Malta | U.K. | Switzerland | Poland | Portugal | Romania | Slovakia | Slovenia | Spain | Sweden | Hungary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| min | 7.0 | 5.7 | 4.2 | 2.1 | 2.8 | 2.8 | 7.5 | 5.5 | 8.6 | 4.6 | 4.4 | 3.6 | 2.5 | 6.0 |
| max | 14.5 | 15.6 | 9.6 | 5.1 | 4.3 | 4.1 | 14.3 | 8.9 | 14.9 | 11.3 | 10.6 | 6.7 | 4.3 | 9.9 |
| mean | 9.6 | 9.3 | 6.6 | 3.3 | 3.1 | 3.3 | 9.5 | 6.9 | 10.6 | 6.2 | 6.2 | 4.4 | 3.1 | 6.9 |
| stdev | 2.1 | 2.8 | 1.4 | 1.0 | 0.5 | 0.4 | 2.2 | 1.2 | 2.0 | 1.9 | 1.7 | 1.0 | 0.6 | 1.2 |
| cv(%) | 22.2 | 30.0 | 21.5 | 28.9 | 16.3 | 12.4 | 22.8 | 17.5 | 18.8 | 30.2 | 26.4 | 23.4 | 18.6 | 17.2 |

*Source*: Own computation, based on the data from Eurostat (europa.eu): https://ec.europa.eu/eurostat/web/main/data/database

The series boxplots are shown in Figure 3. Most series present outliers. Data varies in a large range for some countries (Greece, Poland, Lithuania). The lowest ranges are noticed for U.K., Sweden, and Switzerland.

*Figure no. 3. Boxplots of the deceased series*




*Source:* Chart generated using the R software

Table 2 contains the results of the statistical tests performed on the deceased series. From the second column, it results that for Bulgaria, Malta, Switzerland, and Hungary, the hypothesis that there is no monotonic trend of the data series could not be rejected. For the other series, the null hypothesis has been rejected. The slopes computed by Sen's nonparametric method are given in the third column.

*Table no. 2. Results of the statistical tests on the deceased series*

| Country | p-val. MK test | Sen slope | p-val. KPSS level | p-val. KPSS trend | Country | p-val. MK test | Sen slope | p-val. KPSS level | p-val. KPSS trend |
|---|---|---|---|---|---|---|---|---|---|
| Austria | 0.0002 | -0.350 | 0.4761 | 0.0436 | Latvia | 0.0097 | -0.486 | 0.0711 | 0.1000 |
| Belgium | 0.0000 | -0.350 | 0.0456 | 0.1000 | Lithuania | 0.0011 | -0.650 | 0.0447 | 0.0850 |
| Bulgaria | 0.1844 | -0.300 | 0.1000 | 0.0868 | Luxembourg | 0.0115 | -0.200 | 0.0846 | 0.1000 |
| Czechia | 0.0008 | -0.328 | 0.0520 | 0.0427 | Malta | 0.1611 | 0.100 | 0.1000 | 0.1000 |
| Cyprus | 0.0430 | -0.367 | 0.0753 | 0.0520 | U.K. | 0.0048 | -0.050 | 0.0797 | 0.0541 |
| Croatia | 0.0011 | -0.480 | 0.0615 | 0.0460 | Switzerland | 0.2064 | -0.050 | 0.1000 | 0.0413 |
| Danemark | 0.0036 | -0.250 | 0.0759 | 0.0610 | Poland | 0.0001 | -0.520 | 0.0475 | 0.0394 |
| Estonia | 0.0017 | -0.367 | 0.0442 | 0.0610 | Portugal | 0.0188 | -0.329 | 0.0950 | 0.1000 |
| Finland | 0.0073 | -0.133 | 0.0481 | 0.0484 | Romania | 0.0100 | -0.420 | 0.0746 | 0.0705 |
| France | 0.0036 | -0.187 | 0.0600 | 0.0961 | Slovakia | 0.0023 | -0.280 | 0.0612 | 0.0498 |
| Germany | 0.0010 | -0.150 | 0.0470 | 0.0207 | Slovenia | 0.0008 | -0.400 | 0.0473 | 0.0725 |
| Greece | 0.0001 | -0.876 | 0.0537 | 0.0635 | Spain | 0.0169 | -0.217 | 0.0847 | 0.0543 |
| Ireland | 0.0007 | -0.240 | 0.0495 | 0.0966 | Sweden | 0.0188 | -0.110 | 0.0826 | 0.0361 |
| Italy | 0.0004 | -0.233 | 0.0576 | 0.0469 | Hungary | 0.2020 | -0.180 | 0.1000 | 0.0571 |

*Source:* Own computation

The series stationarity in level (the fourth column of Table 1) has been rejected for Belgium, Estonia, Finland, Germany, Ireland, Lithuania, Poland, and Slovenia series. The trend stationarity has been rejected for nine series, among which Italy, Switzerland, Poland, and Slovakia (last column, Table 2). So, the stationarity hypothesis in trend and level couldn't be rejected only for the series recorded in Finland, Germany, and Poland.

Three were clusters provided by the k-means algorithm. The following countries are contained by the clusters:

1. Denmark (7), Finland (9), Germany(11), Ireland (13), Malta(18), UK(19), Switzerland(20), Spain (26), Sweden (17).

The countries in the last cluster have a standard deviation between 0.4 and 1.4 and an average between 3.1 and 4.9. Half series are nonstationary in level or variance. All series but Malta and Switzerland have a negative trend.

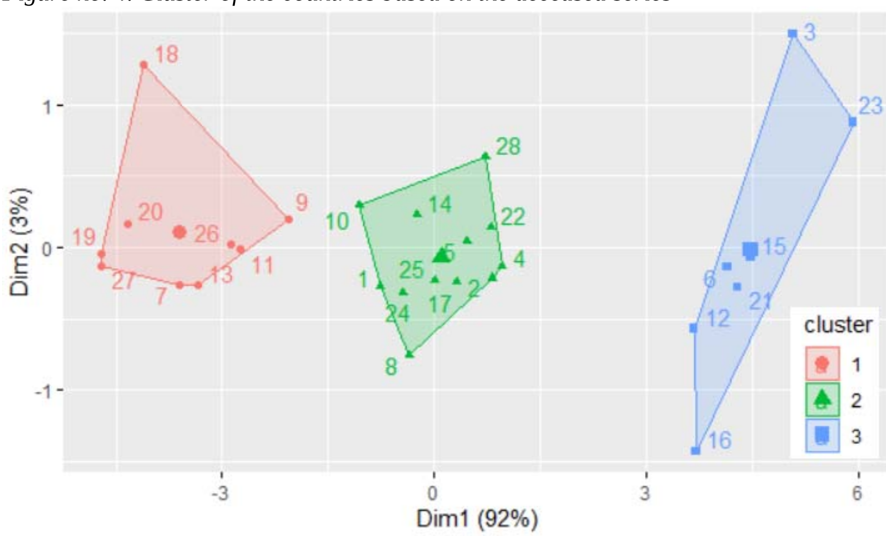
2. Austria (1), Belgium (2), Czech Republic (4), Cyprus (5), Estonia (8), France (10), Italy (14), Luxembourg (17), Portugal (22), Slovakia (24), Slovenia (25), Hungary (28).

This cluster is formed by the series with an average above 6.1 and standard deviations between 0.9 and 1.9.

3. Bulgaria (3), Croatia (6), Greece (12), Latvia (15), Lithuania (16), Poland (21), Romania (23).

This cluster contains the countries with the highest average (above 9.2) and the highest variation coefficients. Almost all are stationary in level, and all but Poland are stationary in trend.

*Figure no. 4. Cluster of the countries based on the deceased series*




*Source:* Result of the k-means algorithm. Output from R software

### 4.2. Results on the pollution series

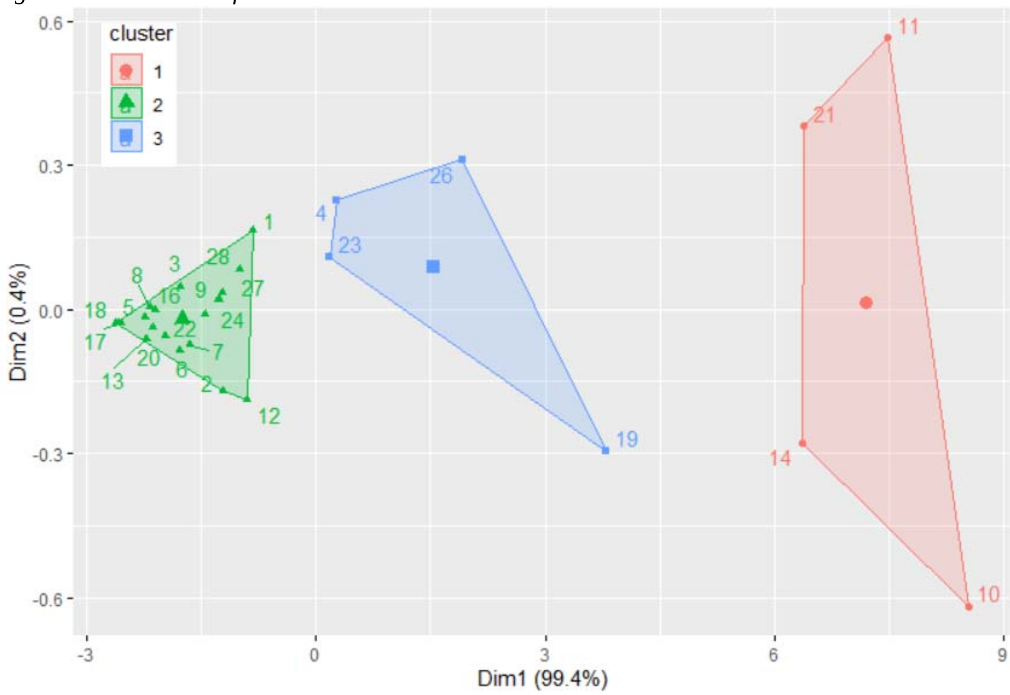
The Mann-Kendall trend did not reject the hypothesis of a decreasing trend of CO volume for all, but Austria, Ireland and Greece.

At a significance level of 5%, the stationarity hypothesis was rejected for series from Austria, Bulgaria, Czech Republic, Germany, Romania, and Hungary. At the same significance level, for half series, the level stationarity was rejected. But, at a significance level of 4.5%, the null hypothesis could not be rejected for all series.

The optimal number of clusters was determined to be 3. Running the k-means algorithm, the clusters contain (Figure 5):

1. France, Germany, Italy, and Poland. These are the countries with the highest production of CO in Europe. Germany and Polland have a variation coefficient greater than 10%, while this coefficient is about 5% for the other two countries.
2. The Czech Republic, UK, Romania, and Spain.
3. The other countries.

*Figure no. 5. Clusters of the countries based on the CO series*




*Source:* Result of the k-means algorithm, Output from R software

## 5. Conclusions

In this article, we analyzed two aspects related to the implementation of 'intelligent' transport rules. The first one, related to the number of death from car accidents, show a decreasing trend in all countries. Stationarity in mean and trend of pollution with CO is noticed. At the regional level, the average series presents a significant decreasing trend. The comparison of the two groups of clusters leads to the following conclusions. The Czech Republic and Poland keep their position in clusters 2 and 3, respectively. The cluster that contains the series with similar behavior relative to both criteria is the first one, including Denmark, Finland, Ireland, Malta, Switzerland, and Sweden.

The study should be extended to other aspects related to diminishing the impact of anthropic activity on the environment.

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