Gradus Vol 8, No 2 (2021) 52-58
ISSN 2064-8014

# STATISTICAL ANALYSIS OF FREIGHT TRANSPORT IN THE EUROPEAN UNION

*Adrienn Boldizsár*[1*]

[1] Department of Logistics Technology, GAMF Faculty of Engineering and Computer Science, John von Neumann University, Hungary
https://doi.org/10.47833/2021.2.ENG.002

***Keywords:***
Freight transport, European Union, descriptive statistics, normal distribution

***Article history:***
Received 5 May 2021
Revised 20 May 2021
Accepted 27 May 2021

***Abstract***
*The European Union's transport policy aims to ensure the smooth, efficient, safe and free movement of people and goods throughout the Union through integrated networks using all modes of transport (road, rail, water and air). EU policy also covers a wide range of issues, such as climate change, passenger rights, clean fuel and reducing the administrative burden of port customs clearance. In my research, I examined the transport policy aspirations of the last 20 years with statistical tools in terms of the current role of each transport sector in the life of the member states.*

## 1 Introduction

The transport sector - including freight transport - has undergone a number of changes in recent decades. One of the reasons is the growing demand for faster and cheaper services and the emergence of a consumer society, mainly due to globalization. All this meant that the volume of road freight transport increased significantly in recent years [5].

This is mainly due to the following changes, such as the transformation of industrial production structures, which have reduced the demand for bulk transport while increasing the demand for fast and timely services. Another reason is the change in production sites, which has increased the demand for freight. The increasing level of urbanization, which also increased the demand for transportation services leading to retail chains. The geographical exchange of goods and economic cooperation has changed, increasing the demand for international transport. The emergence of retail structures is also an important factor that increases the demand for freight transport from manufacturing plants to logistics centers and from logistics centers to commercial facilities. I would also highlight the development of E-commerce [10]. This has received particular emphasis due to the current pandemic situation in 2020 (Covid-19 epidemic).

As a result, I come across a number of studies that predict that in the coming years - contrary to the aspirations of the European Union in the field of transport policy - road freight transport will continue its upward trend [6]. All this has resulted not only in the growth of road freight transport, but also in the transformation of freight transport chains.

Based on this line of thought, I examined how road and rail freight performance in the European Union developed in 2016 by country. As a null hypothesis, I formulated whether the distribution of the 2016 road and rail data series approached each other, with which I wanted to examine whether road and rail show similarities, and whether the two data series have a similar distribution. I first performed a $\chi^2$-test on the data to see if they followed a normal distribution. Next, by selecting the appropriate statistical test — which in this case was the Wilcoxon Rank Sum Test — I examined whether the two data sets were equally distributed. After completing the Test, I examined the freight

* Corresponding author. Tel.: +36 30/3789713
E-mail address: boldizsar.adrienn@gamf.uni-neumann.hu

intensity indicators of each Member State in order to get a more nuanced picture of the role of each Member State in the freight transport of the Union. I then examined how the $CO_2$ emission values, taking into account the transport sub-sectors, evolve on the basis of the baseline data, weighting the emission values by each mode of transport.

## 2 European Union transport policy and future of freight transport

Trends in freight transport in European Union are mostly examined in the literature from the perspective of road freight transport. Article VI of the Treaty on the Functioning of the European Union One of the Union's most important common policies is the transport policy governed by Title II. The future of the region is largely determined by the 2011 White Paper, whose 40 initiatives will help growth, create jobs, reduce dependence on imported oil and reduce the sector's $CO_2$ emissions by 60% by 2050 [9]. Figure 1 shows the expected trends in freight transport in the European Union up to 2050.

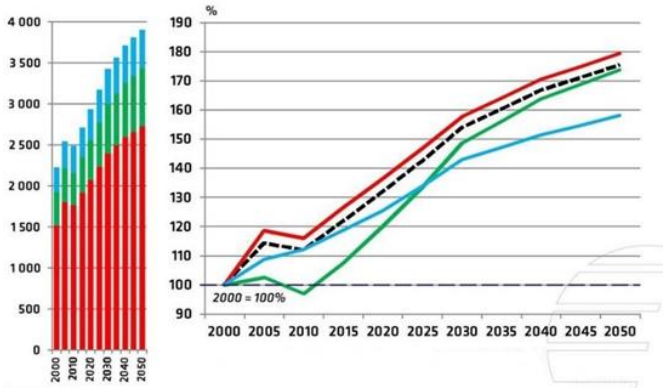


*Figure 1. Freight trends by 2050 in the EU (black dashed - freight performance, red - truck, blue - inland waterways, green – rail – million km) [Source: 4]*

Transport is a fundamental sector of the economy. It comprises a complex network of around 1.2 million private and public companies in the European Union, providing employment for around 10.5 million people. One of the main challenges for the EU transport sector is to create a well-functioning Single European Transport Area, connecting Europe to modern, multimodal and safe transport infrastructure networks and moving towards lower levels of mobility. This includes reducing other negative externalities of transport. From a social point of view, affordability, reliability and accessibility of transport are essential, in both long distance and urban environments [8]. However, this has not been fully achieved, but in the long run, addressing these challenges will help achieve sustainable growth in the EU [3]. Part of all this is that we can make a big contribution to success if we pay much more attention to these measures, not just in the area of freight transport, but also in the area of passenger transport. [2]

## 3 Comparison of freight transport sectors in the European Union using statistical tools

After reviewing the current and possible future situation, I examined the results of descriptive statistical tools so often used in practice from the data on freight transport in the Member States of the European Union. The data are from 2016, as this is the last year from which it currently has a well-known and complete data set for rail freight. [7]

### 3.1 General analysis of EU member states from the perspective of freight transport

To analyze the data, I used an Excel spreadsheet, with the help of which was examined the descriptive statistical properties, expected value, standard deviation, minimum, maximum value, etc. of each transport sector, such as road, rail, inland waterway, maritime and air. From the point of view of this research, I also consider the analysis necessary in order to make the freight transport volumes of each transport sector exactly comparable. All of this is shown in Table 1.

*Table 1. Descriptive statistics of the 28 European Union member states from the perspective of freight transport in 2016 [Source: own edit]*

| [thousand tons] | Rail | Road | Inland water | Maritime | Air |
|---|---|---|---|---|---|
| **Expected value** | 62 397 | 527 596 | 71 538 | 167 896 | 582 |
| **Median** | 47548 | 216 107 | 9 071 | 91 344 | 122 |
| **Standard deviation** | 15771 | 705 885 | 114 031 | 177 752 | 1 042 |
| **Minimum** | 581 | 19 682 | 832 | 3 788 | 8 |
| **Maximum** | 363 512 | 3 111 858 | 361 354 | 588 772 | 4 467 |
| **Sum** | 1 559 921 | 14 245 083 | 929 994 | 3 861 616 | 16 305 |

The same data were also plotted in diagrams for better transparency (Figure 2/a, 2/b).

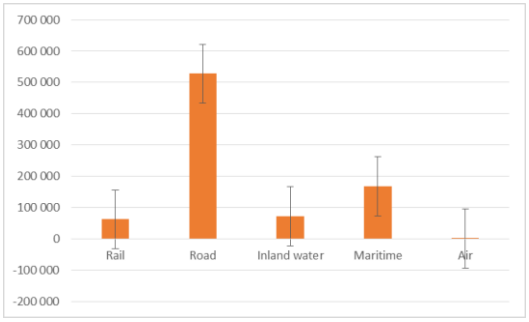


*Figure 2/a. Average quantities shipped and their variance in 2016 [Source: own edit]*

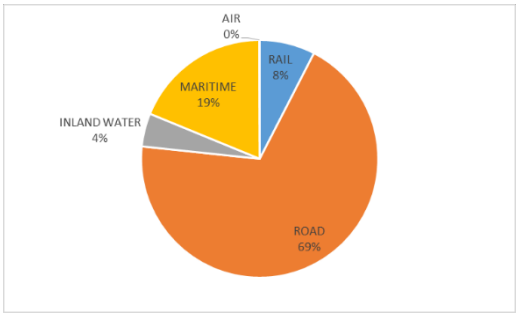


*Figure 2/b. Ratio of total quantities shipped [Source: own edit]*

The results show that in 2016, road freight transport remained the most dominant mode of freight transport in the Union, in line with previous efforts. In Figure 2 / a, the error bars are also shown, representing a standard error of 5%. On this basis, I examined whether the European Union had succeeded in meeting the conclusions of the 2001 and 2011 White Papers that is, shifting quantities from road to other transport sectors that promote sustainable transport, most notably rail.

### 3.2 Hypothesis testing

Road and rail data for 2016 were still used in the study. As a first step, I examined whether the data set follows a normal distribution, and in light of this, I later determined the methodology of our study. The normality test was performed using the $\chi^2$-test because it can be used well for fit tests when it was decided if the sample can come from a given distribution [13]. For this, I generated a normally distributed data set based on the expected value and standard deviation of the data sets for both road and rail data, for which I performed the fit test. I found that there is no correlation between the observed and derived data, they are completely independent of each other, so the original data set does not follow a normal distribution.

Wilcoxon's rank-sum test is useful for comparing two populations to which observations are paired and the sample is not normally distributed as in our case. The null hypothesis of the test is that the median difference between the two populations is zero. During the test, the absolute values of the differences are ranked from smallest to largest, regardless of their sign. This is followed by the sum of the rows of positive and negative differences; that is, the smallest observation denoted by 1 and the largest observation by n. Σ (+) is the sum of the rankings of positive differences and Σ (-) is the sum of the rankings of negative differences [13]. Wilcoxon T statistics are defined as the smaller of the two rankings as follows:

$$T = \mathrm{MIN}\left[\sum(+), \sum(-)\right] \tag{1}$$

As the sample size increases, the distribution of the T statistic approaches the normal distribution; convergence to a normal distribution is good for n ≥ 25. The mean of the T distribution is given by:

$$E(T)=\frac{n(n+1)}{4}, \tag{2}$$

the standard deviation:

$$\sigma_T=\sqrt{\frac{n(n+1)(2n+1)}{24}}, \tag{3}$$

and large sampling test statistics:

$$Z^*=\frac{T-E(T)}{\sigma_T} \tag{4}$$

The test was performed with a free program called PSPP [11]. Comparing the road and rail values, the following result was obtained (Figure. 3).

$H_0$: road and rail data are equally distributed,
$H_1$: the distribution of railway data is larger.

NPAR TEST
/WILCOXON Valtozo0001 WITH Valtozo0002 (PAIRED).

Rangok

| | | N | Mintaátlag rangja | Rangok összege |
|---|---|---|---|---|
| Valtozo0001 - Valtozo0002 | Negatív rangok | 27 | 14,00 | 378,00 |
| | Pozitív rangok | 0 | NaN | ,00 |
| | Egyezések | 1 | | |
| | Összesen | 28 | | |

Próbastatisztika

| | Valtozo0001 - Valtozo0002 |
|---|---|
| Z | -4,54 |
| Aszimp. szig. (2-farkú) | ,000 |

*Figure 3. Wilcoxon test results in PSPP [Source: own edit from PSPP]*

The result shows a significant difference between rail and road data, Z = -4.54, for each Member State the road is much more popular than rail freight. All this means that our result is significant, our null hypothesis can be rejected.

## 4 Other indicators in freight transport

In transport, a number of indicators, KPIs*, have been developed to examine data sets. Selecting from these, I performed the following studies.

* Key Performance Indicators

### 4.1 Freight intensity calculation

Using an indicator also used in an international study, the Sustainable Land Transport Indicators on Energy Efficiency and Greenhouse Emissions in ASEAN*, I looked at how countries'tonne-kilometer performance relates to GDP, which gives freight intensity. It has been determined that the goods transported (in tonnes-km) are divided by the level of the gross domestic product of the economy [1]. For the calculation, based on OECD Database, I only had data in freight tonne-km for road, rail and inland waterways, so I took these values into account based on the 2016 data. The results are shown in Figure 4.

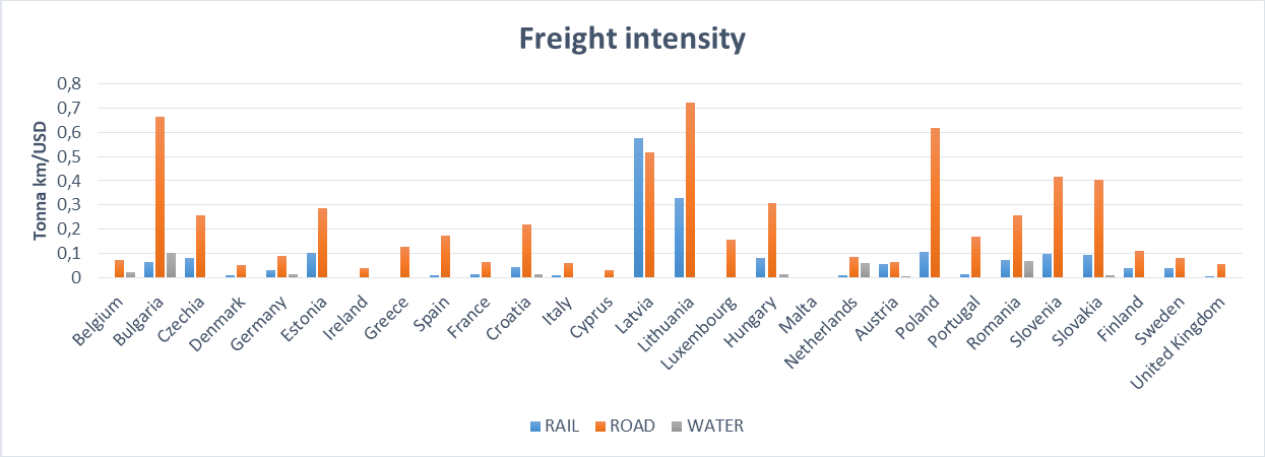


*Figure 4. Development of freight transport intensities in the EU member states [Source: own edit]*

The chart also clearly shows that in 2016, in addition to the almost 15-year-old European regulation, road freight transport is still the most significant. Surprisingly, in terms of intensity, Lithuania, Bulgaria and Poland are in the top three in road freight transport. All this means that the existence of road freight transport contributes greatly to their economic development. In terms of railways, Latvia, Lithuania and Estonia are the most prominent, in which case we can assume that their geographical context and historical past also contribute to all this. This may hold further research potential.

### 4.2 Investigation of $CO_2$ emissions

Nor can it be overlooked that the choice of mode of transport has a significant effect on the amount of $CO_2$ emitted during the transport of goods. As a final consideration, I examined how the freight performance of each sub-sector develops when weighted as a function of $CO_2$ emissions. The weights were given relative to each other in proportion to the total emissions shown in Table 2.

*Table 2. $CO_2$ emission weights [Source: own editing based on 12]*

| | *$CO_2$ (g/tkm)* | *Weight number* |
|---|---|---|
| *Air* | *500* | *0,7194* |
| *Modern truck* | *105* | *0,1511* |
| *Modern train* | *65* | *0,0935* |
| *Modern ship* | *25* | *0,0360* |
| *Sum* | *695* | *1* |

Marine and inland water performance were considered in this case combined. Figure 5 shows freight performance by the transport sector, while Figure 6 shows the same values weighted as a function of $CO_2$ emissions.

* Association of Southeast Asian Nations

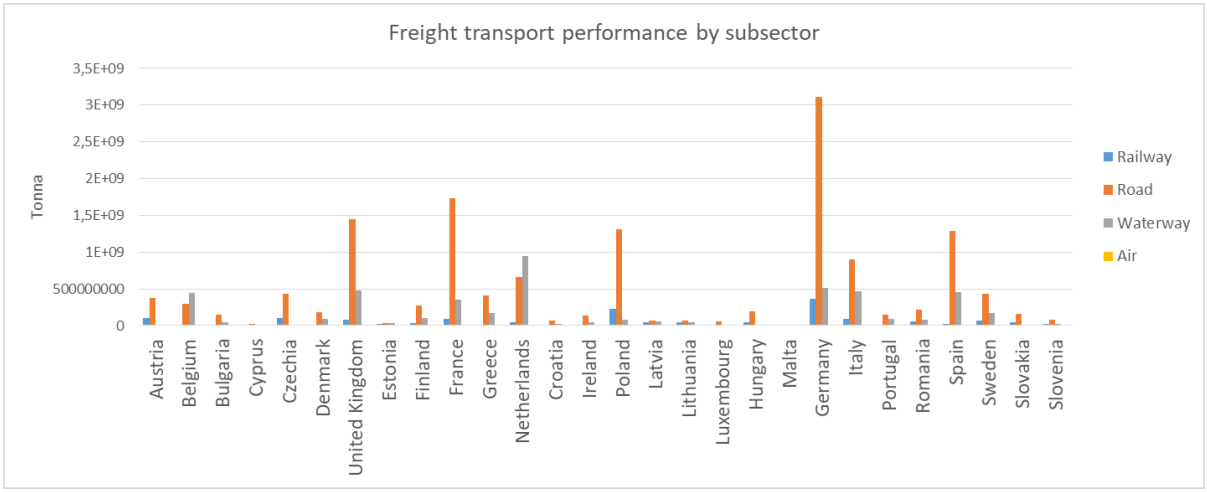


*Figure 5. Freight transport performance by transport subsector [Source: own edit]*

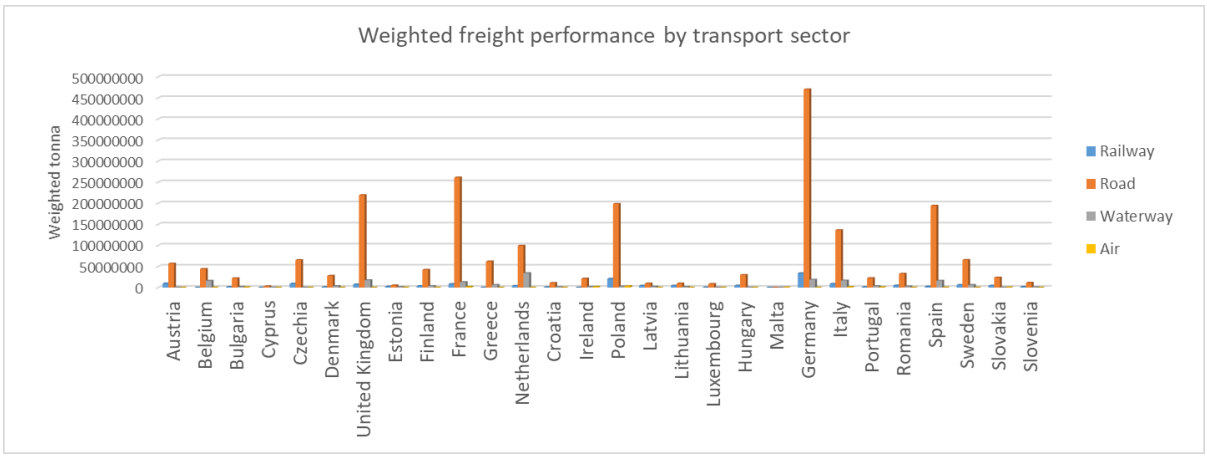


*Figure 6. Development of weighted freight performance by transport subsector [Source: own edit]*

Due to the high weight of aviation, the result could be a spectacular increase in its ratio to total performance. In contrast, this has not been the case and, in fact, still does not appear to a greater extent than in other, mainly road freight transport. Overall, regardless of the weights, the highest $CO_2$ emissions are found in road freight transport in Germany.

## 5 Summary

My research aimed to examine the member states of the European Union from the perspective of freight transport, and it was reviewed the transport policy aspirations so far. From our statistical analysises, I have obtained the result that Member States' significant amount of freight transport is still carried out by the road. As a further research topic, I have marked the effects that this may have on Hungary in terms of freight transport, and in the case of domestic supply chains and networks. Another interesting question is, for example, what statistical results the current epidemic situation will show in the future, once we have accurate data.

## Acknowledgment

This research is supported by EFOP-3.6.1-16-2016-00006 "The development and enhancement of the research potential at John von Neumann University" project. The Project is supported by the Hungarian Government and co-financed by the European Social Fund.

## References


[1] ASEAN Secretariat (2019). Guidelines on Sustainable Land Transport Indicators on Energy Efficiency and Greenhouse Gas (GHG) Emissions in ASEAN. Jakarta, ISBN 978-602-5798-33-7

[2] Bánfi, M. G., Mészáros, F., Bokor, Z. (2014). Zöldülő vicinálisok Európában: Energiahatékonysági és környezetvédelmi szempontok a regionális vasúti közlekedésben, INNORAIL MAGAZIN 1: 2 pp. 48-53. 6 p.

[3] Hololei, H., Bulc, V. (2019). Mobility and Transport, Transport in the European Union: Current Trends and Issues, Available: https://ec.europa.eu/transport/sites/transport/files/2019-transport-in-the-eu-current-trends-and-issues.pdf, (Downloaded: 18.08.2020)

[4] Közlekedéstudományi Intézet (2018). Trendek 2050-ig - Áruszállítási teljesítmények az UE28-ban, Available: http://www.kti.hu/trendek-archivum/trendek-2050-ig-aruszallitasi-teljesitmenyek-az-eu28-ban/ (Downloaded: 07.08.2020)

[5] Mesjasz-Lech, A., Nowicka-Skowron, M. (2013). "Globalization and the development of logistics infrastructure of the freight transport by road," ERSA conference papers ersa13p345, European Regional Science Association.

[6] Nowakowska-Grunt, J., & Strzelczyk, M., (2019). The current situation and the directions of changes in road freight transport in the European Union, Transportation Research Procedia, Volume 39, Pages 350-359, ISSN 2352-1465, https://doi.org/10.1016/j.trpro.2019.06.037.

[7] OECD Database (2020). https://data.oecd.org/transport/freight-transport.htm (Downloaded: 08.09.2020)

[8] Ogunkunbi, G. A., Mészáros, F. (2019). Access Control of Urban Transport and the Environment: The Past, Present and Prospects, Conference on Transport Sciences, Győr 2019

[9] Ottemöller, O., Friedrich, H. (2016). Opportunities of sectoral freight transport demand modelling, Case Studies on Transport Policy, Volume 4, Issue 1, Pages 9-12, ISSN 2213-624X, https://doi.org/10.1016/j.cstp.2015.08.003.

[10] Pieriegud, J., Paprocki, W., Wolański, M., Hoszman, A., Matczak, M. (2015). System transportowy Polski. 10 lat w Unii Europejskiej [Poland's Transport Sector. 10 years of EU membership]. ISBN: 978-83-7378-979-1

[11] PSPP Program: https://pspp.software.informer.com/0.7/ (Downloaded: 10.09.2020)

[12] Time for change, CO2 emissions for shipping of goods. Available: https://timeforchange.org/co2-emissions-shipping-goods. (Downloaded: 31.08.2020)

[13] Washington, P. S., Karlaftis, G. M., Mannering, F. (2003). Statistical and Econometric Methods for Transportation Data Analysis (Chapman & Hall/CRC Interdisciplinary Statistics) 2nd Edition ISBN-13: 978-1420082852