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Adaptive Economic Systems: Analyzing the Influence of Infrastructure, Unemployment and Tourism on Romanian Salaries

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Abstract. *In 1990, the Romanian economy changed in a crucial manner, after the communist regime has fallen, moving from a centralized economy to a capitalist one, introducing also services as a sector apart from industry and agriculture. The 1990s period was a difficult one, due to political instability, which lead to a decrease in Gross Domestic Product. Thanks to the integration of Romania in North Atlantic Treaty Organization and European Union, the Romanian economy started to grow significantly, obtaining over 65 billion euro which facilitate the development of the country. The infrastructure is the sector that benefits from the European Union funds, starting with 113 kilometers in 1990 and achieving a total of 1275 kilometers at the end of 2024. The scope of the research is to identify the contribution of infrastructure – measured through highway kilometers of each county, together with the railway kilometers of each county, tourism – measured through the type of tourists, tourists number per county, and unemployment rate on the evolution of the net salaries per county in RON, using Python programming language. Moreover, the Romanian economy presents the characteristics of a complex adaptive system, which makes it suitable to be analyzed by various algorithms. Using a clustering approach, the counties in Romania have been divided by considering the three types of indicators mentioned above and policy recommendations have been formulated for the counties included in the lower-measured category.*

Keywords: Romania; Gross Domestic Product; Unemployment; Infrastructure; Clustering; Python

Introduction

Between 2000 and 2006, the Romanian Government developed several strategies for transport infrastructure with specific goals by increasing the average speed and improve the traffic, achieving a balance among the repair, modernization, and maintenance, especially for rail network (Popescu & Fistung, 2015). The freight transportation growth significantly between 2000 and 2008, with a

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35% increase, but during the financial crisis, the values decreased strongly, with 21% in 2009 and 42% in 2010, compared to 2008.

The Gross Domestic Product (GDP) quantifies the value in money of the final products and services which are acquired by the clients and produced in a country at a certain period of time (Callen, 2008). In 1989, the GDP was approximately 41.45 billion dollars, while in 1990 decreased by almost 3 billion dollars, to 38.25. The minimum values were in 1992, at 25.12 billion dollars and then it started to slowly increase. Starting with the 21st century, the GDP increased faster, achieving 37.25 billion dollars in 2000, 40.4 billion dollars in 2001, and in 2008 was registered the maximum value up to that moment, with a total of 214.32 billion dollars. Because of the financial crisis, the GDP decreased in 2009 and 2010, having a total of 174.1 billion dollars and 170.03 billion dollars respectively. During the COVID-19 pandemic, the GDP increase was minimum, from 251.02 billion dollars in 2019 to 251.36 billion dollars in 2020. The all-time peak was in 2023, with a total of 356.615 billion dollars (Trading Economics, 2025).

GDP per capita evaluates the social welfare, satisfaction and happiness of population and it has a significant impact on the Human Development Index (Tümer & Akkuş, 2018). The minimum GDP per capita in Romania was in 1992 with a value of 1.102,1 dollars, and the peak was achieved in 2023 with a total value of 18.804,3 dollars (World Bank, 2025).

Similar to adaptive complex systems, the economy is sensible to external factors, but it has the ability to adapt. During the COVID-19 pandemic when the global economy stopped. In 2020, the budgetary deficit was approximately 9%, while in 2021 the deficit was 7% and the situation was comparable for all European countries. A key factor that leads to the difficult economic period is the low value added. Thanks to the European Union (EU), 1.8 billion euro have been offered for Romania in order to combat the negative impact of COVID-19 on economy, providing approximately 800 million euro to small and medium companies (Cristina et al., 2021).

The imports and exports in Romania are majority from EU, with a value for imports of 73.3% and 62.6% for exports, while for the rest of the world, the imports value is 26.7% while the exports value is 27.4%. The GDP per capita in Romania had a deficit of 46% in 2013 compared with EU average and it reduced the gap to 22% in 2023, demonstrating the economic development of the country (Eurostat, 2024).

Inflation is considered as a key macroeconomic indicator, describing an imbalance in the market due to the rise in price level during a specific timespan, reducing the purchasing power of the population. The Monetary institutions have the objective to keep the price stability by implementing policies and to communicating constantly with the population (Mihalache & Bodislav, 2023). Starting with 1990, the inflation rate in Romania continuously increased, achieving a value of 264.7% in March 1992 and it the peak was in 1994, when it was registered the value of 316.9%, in November. Then it started to decrease, up to 1997 when it started again to increase to 177.6% in June. Starting with 2000, the inflation rate decreased, and for 15 years it was below 10%. For the first time, in 2015, up to 2017, the inflation rate was negative, which means that deflation occurred. The opposite of inflation is deflation, when the prices for goods and services decrease, resulting from the contraction of money in the economy (Clarke, 2024).

Regarding the regional development, three of eight regions of Romania are the poorest in the EU. The region with highest development of Romania is the Bucharest. The western, center, and north-western regions have also developed, while the south-western (having a value of 42% of GDP of EU average) and north-eastern (have a 36% GDP value compared to EU mean) regions of Romania suffers from the lack of development and investments (Cristina et al., 2021).

The relationship between inflation and unemployment rate is negative and it can be described by the Phillips curve. Inflation represents a monetary feature, while unemployment is an economic structural metric. In Romania, between 1990 and 2009, the Phillips curve was not respected, due to the fact that unemployment rate was impacted significantly by the regulations and productivity evolution among the employees (Moridian et al., 2024). It was difficult to implement monetary regulations since there was no correlation between inflation and unemployment rate. In the beginning of 1990s' the strategy of Romanian government was different compared to Poland, Hungary, or Slovakia. Instead of a significant restructure which led to a high unemployment rate and a faster recovery of GDP, Romania preferred a low unemployment rate which led to a high inflation, and it took almost 15 years to rebuild the GDP similar with the economic growth of 1989. The unemployment rate is negatively correlated also with the economic growth rate, when the economies increase, the unemployment decreases, and the best examples are during crisis, when unemployment is high, and the economic development is minimum (Moridian et al., 2024).

Unemployment rate represents an important metric that has been analyzed, reporting the percentage of unemployed people, and together with tourists' number, kilometers of highway and railway, will help in dividing the counties in Romania to various groups based on their cumulative performance.

The paper is structured as follows: section 2 discusses the methodology considered in the study, while section 3 is dedicated to discussing the results of the cluster analysis. The works ends with concluding remarks and policy recommendations.

Methodology

The scope of the research is to identify the impact of highway kilometers, electrified railway kilometers, unemployment rate, tourists on the net salary per county in Romania. The data was extracted from Romanian National Institute of Statistics (INS), starting with 1995 up to 2023, for all Romanian counties, with yearly information (National Institute of Statistics, 2025). From INS was extracted the yearly information about net salaries from transport sector, number of Romanian and Foreigners tourists in hotels, unemployment rate, highway kilometers, electrified kilometers of railway.

In the following, few words related to the considered variables are provided, accompanied by a discussion related to the range in which these variables are positioned at Romania's level.

Regarding the variables that have been included into analysis, unemployment rate represents the percentage of workforce people which are unemployed, based on specific particularities such as the age (between 15 and 74), status (available to work and not employed in the analyzed period) (Eurostat, 2025). Between 1997 and 2024, the unemployment rate was below 10% in Romania, which confirms the development of the country, starting with a value of 5.71% in January 1997, and achieving a peak of 8.99% in August 2013, followed by a constant decrease up to the beginning of COVID-19 pandemic, when the unemployment rate increased from 4.68% in January 2020 to 6.65% in June 2020. In December 2024, the unemployment rate was 5.18% (European Central Bank, 2025).

Highways generate economic benefits, providing easy access to local resources, reducing travel time, fuel consumption, pollution and increasing the transport capacity and average speed. Regarding the macroeconomic benefits, highway construction generates jobs, increases not only the GDP of the country, but also the income of stakeholders, standard living and it encourages the tourism industry. The number of highway kilometers opened in Romania started with 2004 shows a continuous investment from the Romanian government: in 2004, 115 kilometers have been

completed, followed by 53 in 2007, 40 in 2009 and 200 kilometers in 2012. In the last years, the number of kilometers was reduced, to only 54 in 2020 and 11 in 2021. In 2022, 53 kilometers have been finalized, followed by 80 in 2023 and in 2024 was registered the peak, with 201 kilometers (130km, 2024; Nela, 2023).

Electrified Railway appeared for the first time in the middle of 19th century, developed by Werner von Siemens provides multiple possibilities of combining with other electrical equipment, offering also a significant traction and power (Koseki, 2010; Schmid et al., 2015). Another advantage of using electric railways is the variety of energy sources, representing one of the main reasons for developing the automobiles industry.

Net Salary represents the amount of money that an employee should receive based on the work that has been done, even if it is working in a private or public sector. The salary in Romania is monthly but the payment date could be different from one company to another. In order to obtain the net salary, from gross salary should be paid taxes and contributions according to Romanian tax legislation. The Romanian government constantly increased the minimum wage, introducing recently a benefit for, excepting from taxation 200 RON for employees which have minimum salary of 3.300 RON gross (Ţop, 2024).

Tourism sector is one of the key sectors of Romanian economy, producing a significant part of GDP. Between 2013 and 2019, the average share of the GDP produced by tourism was approximately 5.70%, but during COVID-19 pandemic, the percentage decreased massively, to 1.88% in 2020, slowly increasing to 2.65% in 2021, 3.42% in 2022, 4.19% in 2023. For 2024 and 2025, the predicted values are 4.95% and 5.72%, demonstrating the positive trend of the sector(Statista, 2023). Regarding the distribution of foreigners tourists that visits Romania, according to Statista (2024), in September 2024, 35.9% of the tourists came from Bulgaria, 29.2% from Hungary, 6.1% from Italy, 6.1% from Poland, 5.9% from Germany, 2.5% from France and the rest of 14.3% represents other EU countries.

A potential focus of the Romanian Government on regional development can be explained by the Corridor IV Pan-European, which is divided into two parts, roads with a total of 3.640 kilometers and railway, with a total of 4.379 kilometers, passing Turkey, Greece, Bulgaria, Romania, Hungary, Slovakia, Austria, Czech Republic and Germany, representing one of the most important commercial routes from Europe, passing from Eastern part of the Europe to the Western part. Through Romania, there are in total 1.162 highway kilometers and 1.280 railway kilometers planned. There are two routes, one for roads and one railway in Romania, via Timisoara, Sibiu, Pitesti, Bucuresti and Constanta for highways and for railways through Arad, Alba Iulia, Brasov, Ploiesti, Bucuresti and Constanta (TINA (Project) et al., 2002).

Regarding the main techniques used in the present paper, it should be noted that clustering is one of the most used unsupervised learning methods which groups the data based on the similarities in multiple clusters, being very useful in exploratory data analysis, recommendation or market segmentation. In order to reduce the distances among the observations and the centroid of the cluster, a K-Means algorithm can be used for clustering (Davis, 2024). Furthermore, for identifying the goodness of a clustering method, a silhouette score or silhouette coefficient can be used, which represents a metric, having values between -1 and 1. In the ideal scenario, the silhouette score would have a value as close as possible to 1, which means that the observations are apart and clearly distinguished, while in an undesirable scenario, a value closer to -1 can be achieved, signifying that data is assigned in a wrong manner (Bhardwaj, 2020).

In order to perform the cluster analysis, Python programming language has been used due to the fact that it is one of the most versatile and strong programming languages. Python became

very popular in last years, thanks to his coding fluency and simplicity, being used in a multitude of applications, such as Machine Learning (ML), Data Analysis, Web Development, Automation, Internet of Things, Scripting or Scientific Computing (Hill, 2023). The main advantages of Python is that it has one of the largest and active communities, which contributes to the development of language, helping also the developers, is easy to learn and read, it has a variety of libraries that contains functions that facilitate the code implementation and is simple to develop prototypes (Hill, 2023). Regarding the ML and Data Analysis approach in Python, there are libraries which provide tools and functions to clean, handle and plot the data, adapting the statistical tests to the needs, offering also the possibility of implementing deep learning solutions.

For developing, editing and publishing programming language code, Visual Studio Code has been used. Visual Studio Code represents a free integrated development environment (IDE) that has integrated a series of compilers, together with numerous tools and extensions that can be installed by the user. Multiple programming languages can be used on Visual Studio Code, such as C++, C#, .NET, PHP, Pyton, Java or Go and the code can be compiled on Windows, Linux or macOS. In our case, Visual Studio Code has been used to integrate Python programming language, merging the datasets and populating the missing years of each county (*Visual Studio*, 2025). Visual Studio Code is one of the most used IDE for Python implementation, thanks to the smart code completion, code debugging and Git integration, having also the possibility to change features or themes (Gupta, 2025).

Results

In order to perform a Data Science approach, the data that has been downloaded from INS website in multiple CSV files, each one containing information about a feature, such as the unemployment rate per county, number of highway kilometers per county, number of electrified kilometers per county, salary per county and the number of employees per county (National Institute of Statistics, 2025).

Using Python programming language functions, the process of dataset cleaning has been performed, removing the columns and rows that are not relevant for the scope of the research, together with the renaming of the columns and values, in order to have standardization and governance. Based on the region name and year that has been analyzed, the join between all five datasets have been accomplished, resulting in a table with 3500 rows and eight columns, which contains information about the hotels from Romania tourist type, region, year, number of tourists, highway kilometers, electrified kilometers of railway, net salaries of transportation sector employees and the average unemployment rate, as it was presented in Figure 1.

	Tourist Type	Region	Year	Number of Tourists	Highway Kilometers	Electrified Kilometers of Railway	Net Salaries	Average Unemployment Rate (%)
0	Romanians	Bihor	2020	171209	5	0	2033	1.37
1	Romanians	Bihor	2020	171209	5	0	2033	2.02
2	Romanians	Bihor	2021	294239	5	0	2210	2.02
3	Romanians	Bihor	2021	294239	5	0	2210	1.58
4	Romanians	Bihor	2022	369549	5	0	2529	1.58
...	...	...	...	...	...	...	...	...
3497	Foreigners	Timis	2021	32791	108	113	2761	0.80
3498	Foreigners	Timis	2022	54451	108	126	3245	0.80
3499	Foreigners	Timis	2022	54451	108	126	3245	0.75
3500	Foreigners	Timis	2023	72121	108	126	3881	0.75
3501	Foreigners	Timis	2023	72121	108	126	3881	0.84

3500 rows × 8 columns

Figure 1 Dataset Overview

Source: Authors' own research.

For the following figures, an aggregation function has been created, in order to calculate the average for each metric on each county. Figure 2 explores the mean unemployment rate of each Romanian region. The red line is the average of all unemployment rates of all regions, having a value of. As can be observed, the majority of 5.62%. The counties with the highest unemployment rate are Vaslui, with 10.49%, followed by Teleorman with 8.89%, Mehedinti with 8.87%, Galati with 8.69% and Buzau with 8.37%. The countries with the lowest unemployment rate are Timis with 1.15%, followed by Bihor with 1.54%, Ilfov with 2.00%, Arad with 2.14% and Bucuresti with 2.19%.

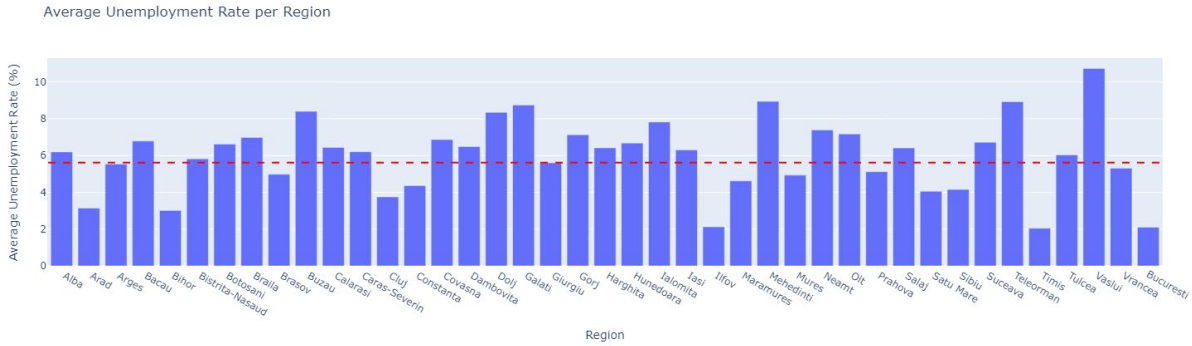

Figure 2 Average Unemployment Rate per Region

Source: Authors' own research.

Figure 3 explores the average salaries for each county between 1995 and 2005. The highest salary was in Ilfov county, with an average value of 508,38 RON, followed by Bucuresti with 402.43 RON, Constanta with 384.68 RON, Calarasi with 362.17 RON and Vrancea with 346.15 RON. Counties with least salaries are Maramures with an average net salary of 231.49 RON, Neamt with 233.49 RON, Giurgiu with 235.38 RON, Covasna with a value of 246.25 RON and Dambovita with a mean salary of 246.81 RON. The average Romanian salary between 1995 and 2005 was 301.47 RON.

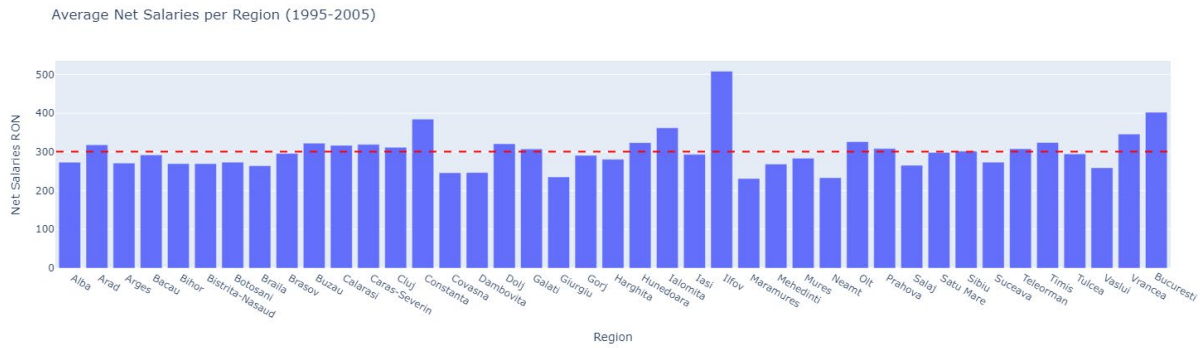

Figure 3 Mean Net Salaries per Region between 1995 and 2005

Source: Authors' own research.

Figure 4 includes the yearly average salaries for each Romanian county between 2006 and 2023. In first place is Ilfov county, with a mean salary of 3.168,52 RON, followed by Bucuresti with 2.757,82 RON, Constanta with 2.399,57 RON, Prahova with 2.205,27 RON and Sibiu with 2.162,96 RON. On the other hand, the counties with the smallest salaries are Botosani which has a mean salary of 1.348m84 RON, Maramures with 1.380,82 RON, Covasna with a value of 1.386,05 RON, Vaslui with a value of 1.395,29 RON and Bistrita-Nasaud with an average net salary of 1.414,88 RON. The average salary in Romania between 2006 and 2023 is 1804.74 RON, almost 6 times higher than 1995-2005 period, showing the growth of the Romanian economy in the recent years.

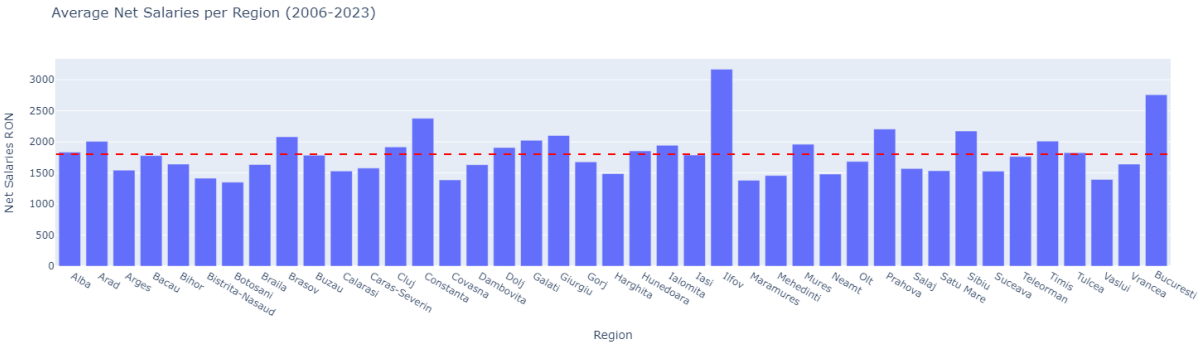

Figure 4 Mean Net Salaries per Region between 2006 and 2023

Source: Authors' own research.

Figure 5 describes the yearly average number of Romanian tourists for each county. The greatest number of tourists are in Constanta, with a total of 750.798, followed by Bucuresti with 489.643, Brasov with 374.752, Prahova with 240.942 and Bihor with 213.885 tourists. The counties with the least tourists are Vrancea with 17.590, Salaj with 12.366, Teleorman with 9.489, Calarasi with 9.165, and Giurgiu with 7.106. The average of Romanian tourists, highlighted by the red line is 114.932 tourists.

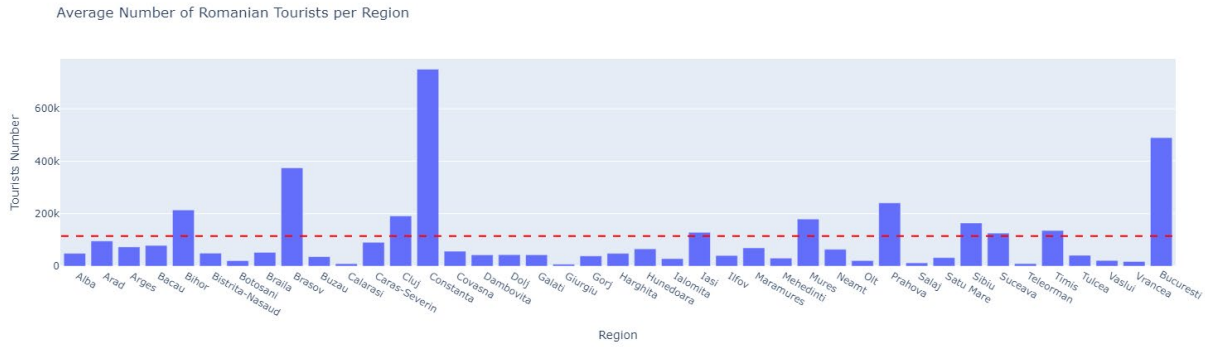

Figure 5 Mean Number of Romanian Tourists per Region

Source: Authors' own research.

Figure 6 presents the yearly average number of foreigner tourists for each Romanian county. As it can be observed, Bucuresti has by far the greatest number of foreigner tourists, with a total of 711.827. In second place, at a very big difference is Brasov county with 83.148 tourists, followed by Sibiu with 77.365, Timis with 75.162 and Cluj with 63.424 tourists. In contrast, Giurgiu county has only 844 tourists, Teleorman 929, Vrancea 1.147, Calarasi 1.874 and Botosani 1.943. According to the information extracted from Figure 6, there is a significant discrepancy between Romanian counties. The average of foreigners' tourists during the analyzed timespan in Romania is 48.940.

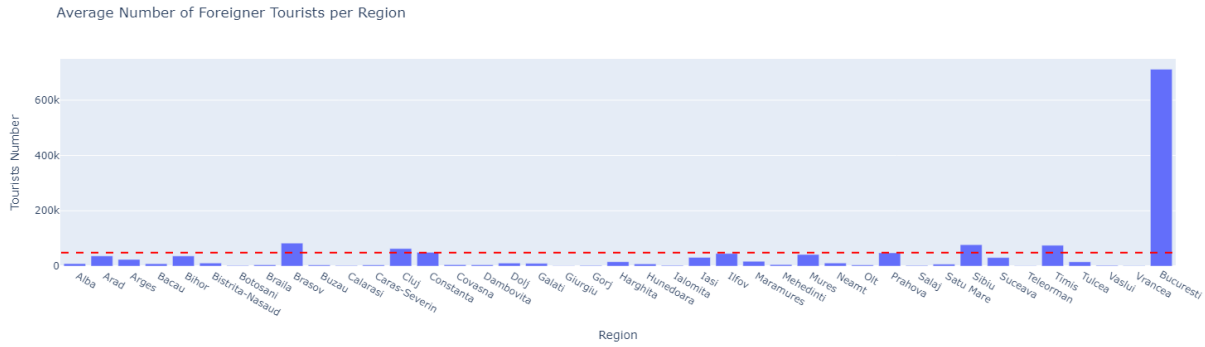

Figure 6 Mean Number of Foreigner Tourists per Region

Source: Authors' own research.

Figure 7 explored the mean highway kilometers in Romania per county. In the first place is Timis county with 108 kilometers, followed by Calarasi with 105 kilometers, Hunedoara with 82 kilometers, Ilfov with 80 kilometers and Alba with 77 kilometers. Bucharest has 22 kilometers, Salaj has 13 kilometers, and Brasov has 6 kilometers. Unfortunately, there are numerous Romanian counties which does not have a single kilometer in highway, 21 in total at the end of 2023, representing one of the main causes of the discrepancy between counties. The mean kilometers of highway per county is 10.47.

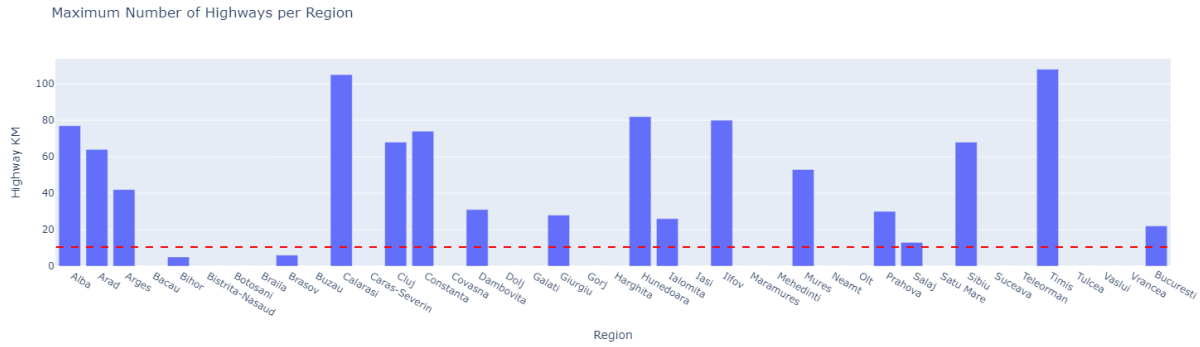

Figure 7 Maximum Number of Highway Kilometers per Region

Source: Authors' own research.

Figure 8 includes the average electrified kilometers of railway per year for each Romanian counties. Suceava is the county with the highest number of kilometers, having 248, followed by Gorj with 239 km, Huneodara with 226 kilometers, Arad with 196 kilometers and Prahova with 194 kilometers. At the same time, there are counties with no electrified kilometers of railway, such as Arges, Botosani, Maramures, Salaj, Satu Maru, Tulcea or Vaslui. Covasna county has only 46 electrified kilometers, while Giurgiu has 48 kilometers. The average electrified kilometers per county in Romania is 95.37.

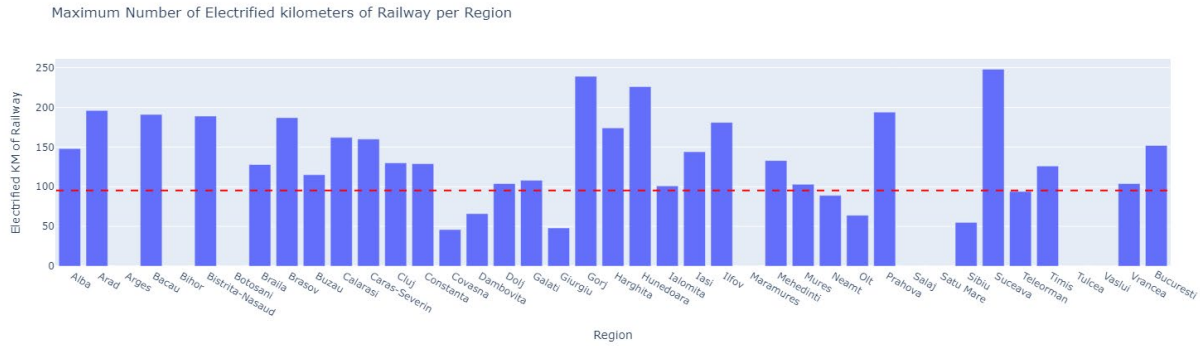

Figure 8 Maximum number of Electrified Kilometers of Railway per Region

Source: Authors' own research.

Figure 9 explores the silhouette score which determines the optimum number of clusters. According to the graphical representation, two is the optimum number since it provides the highest silhouette score. The clustering process has been performed based on the highway kilometers, electrified railway kilometers, net salaries, number of tourists and unemployment rate. In our case, the silhouette score is 0.34, which means that the distance between cluster is significant, but it can be improved, in order to obtain a value as close as possible to 1.

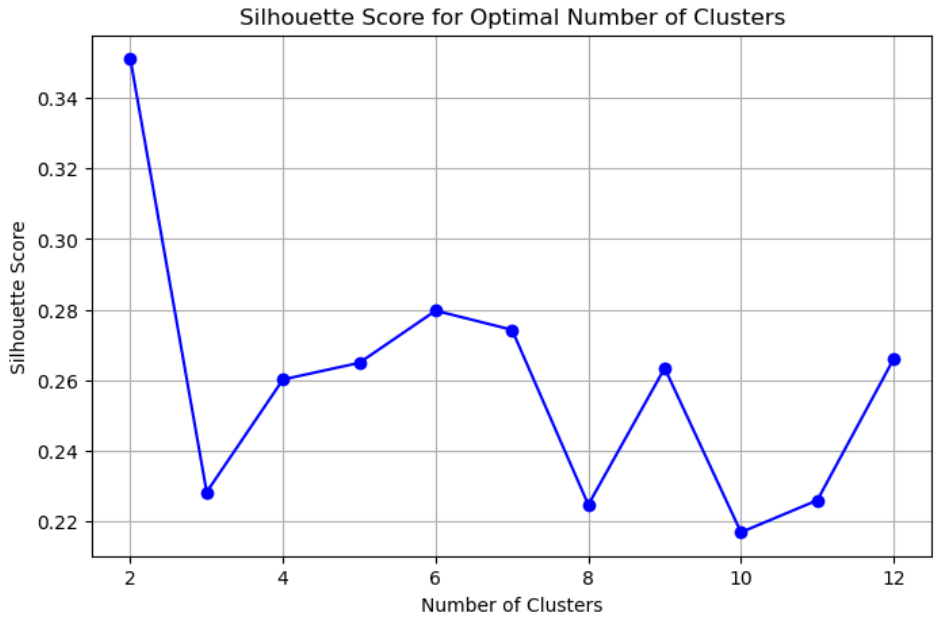

Figure 9 Silhouette graph for optimum number of clusters

Source: Authors' own research.

Figure 10 presents the distribution of highway kilometers for each cluster. For cluster 0, the mean highway kilometers are 18.79, while for cluster 1 are 2.12, highlighting the significant difference among the groups.

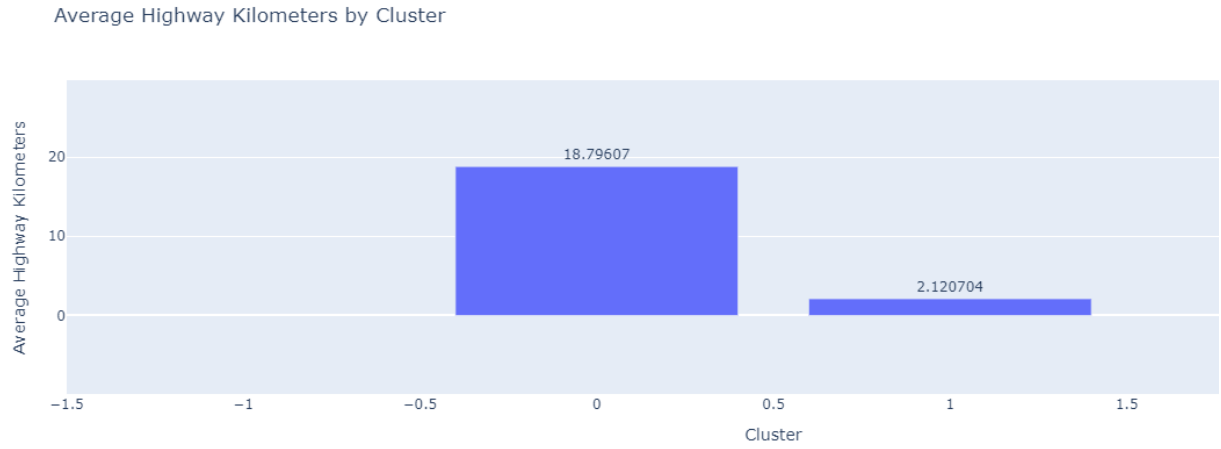

Figure 10 Average Highway Kilometers per Cluster

Source: Authors' own research.

Figure 11 focuses on mean railway kilometers per cluster. The first cluster has a mean of 122.92 kilometers, while the second cluster has a smaller value, just 79.52 kilometers.

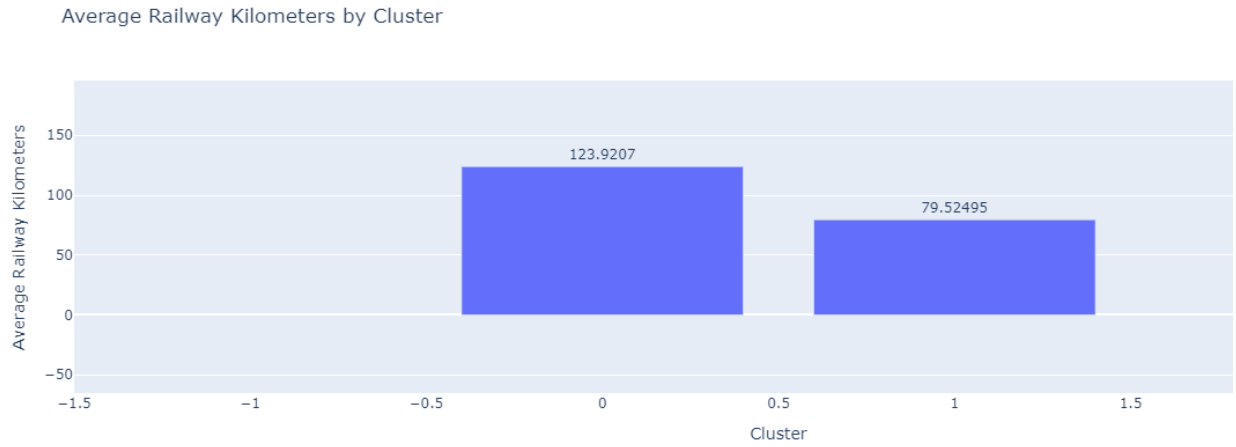

Figure 11 Average Railway Kilometers per Cluster

Source: Authors' own research.

Figure 12 includes the information about the average net salaries for each cluster. Cluster 0 has a mean net salary of 1.826,52 RON, while the second cluster has a mean net salary of 1.386,83 RON.

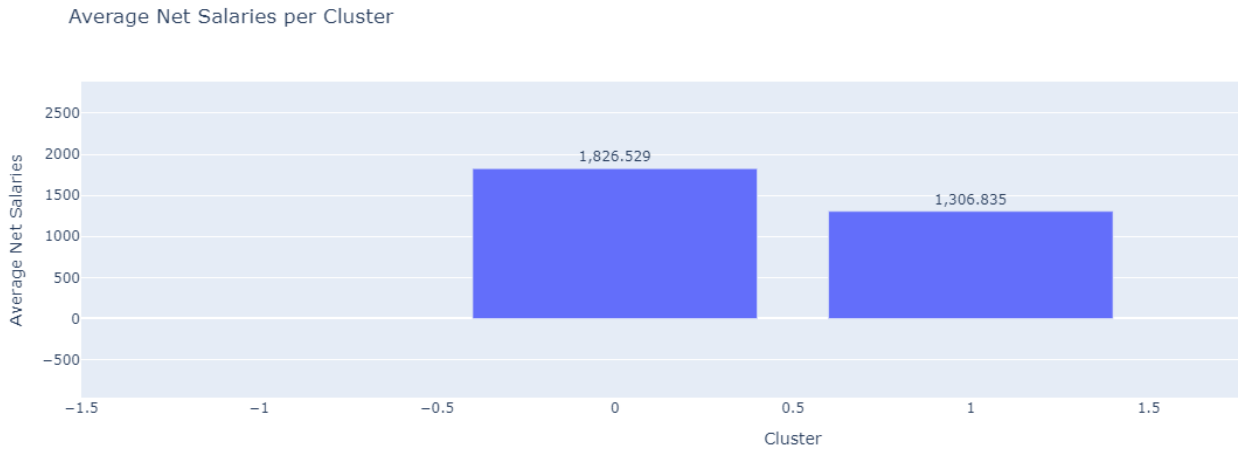

Figure 12 Average Net Salaries per Cluster

Source: Authors' own research.

Figure 13 contains information about the average unemployment rate for each cluster. The cluster 0 has an average of 4.30%, while the second cluster has a higher unemployment rate, with a value of 6.75%.

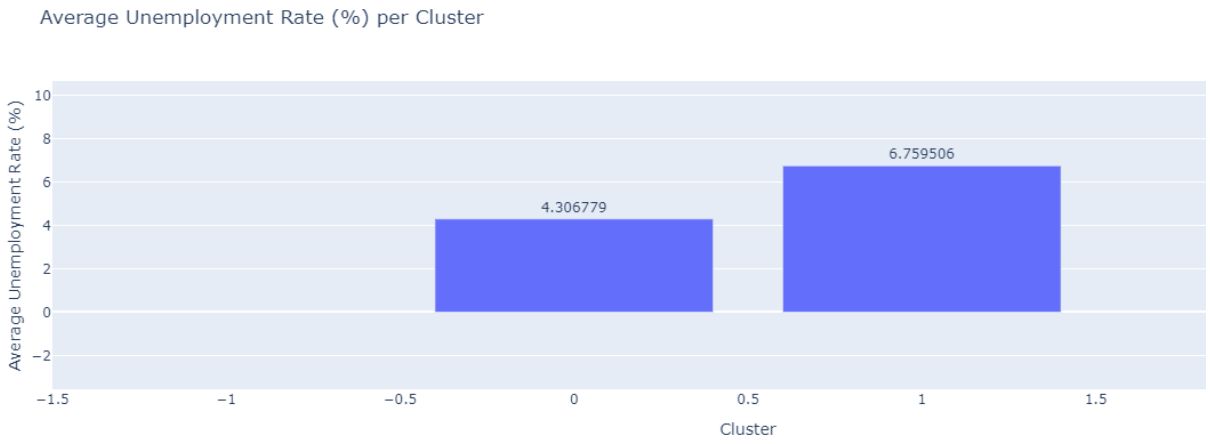

Figure 13 Average Unemployment Rate (%) per Cluster

Source: Authors' own research.

Figure 14 explored the mean tourists for each cluster, separating the counties with an increased number of tourists. The cluster 0 contains an average tourists of 167.78, while the cluster 1 contains only 39.451 tourists.

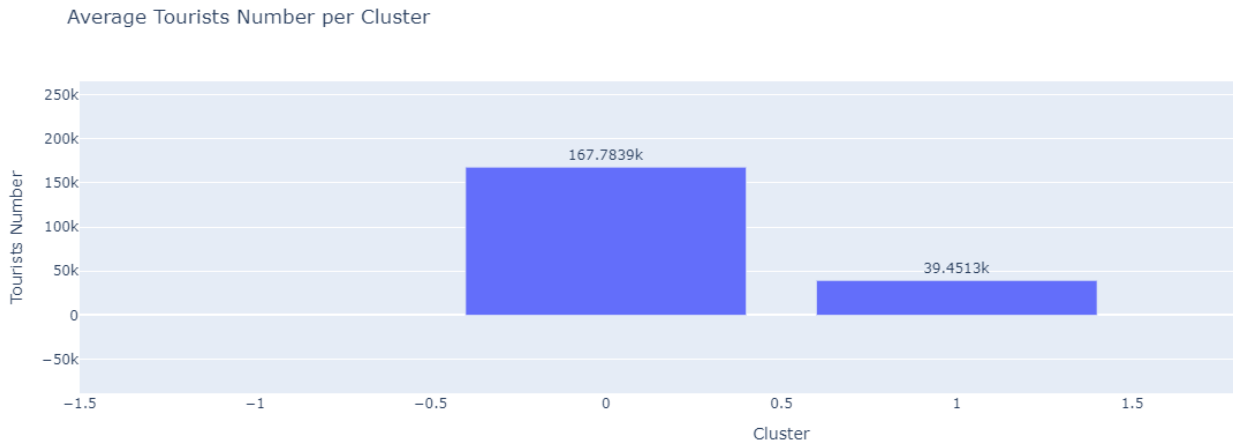

Figure 14 Average Tourists Number per Cluster

Source: Authors' own research.

Using *Geopandas* library from Python, Figure 15 have been created and it includes the Romanian map together with the distribution of each county based on the cluster. As can be observed, the majority of counties, such as Bucuresti, Constanta, Alkba, Arad or Cluj and many others are part of cluster 0, colored in white, while the cluster 1 contains Tulcea, Vaslui, Suceava, Harghita, Covasna, Teleorman and other counties, highlighted in blue.

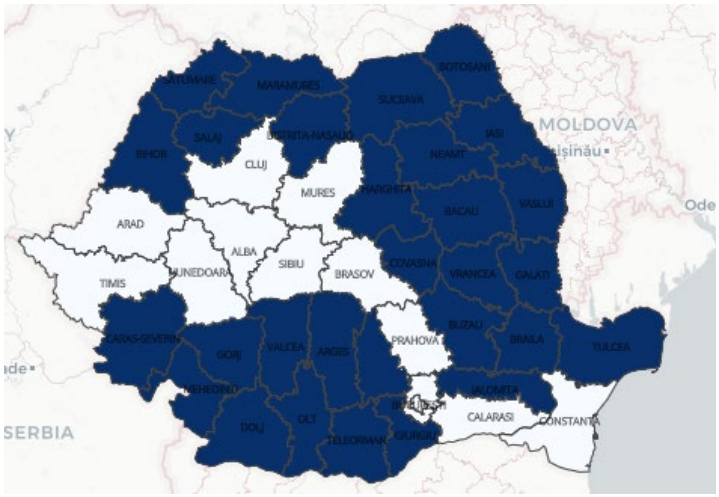

Figure 15 Geographical Representation of Romanian Map with counties distribution in clusters

Source: Authors' own research.

Conclusion

The distribution of counties in cluster highlights the investments and priorities of Romanian government. The majority of the counties with high salaries, increased tourists, highway and electrified railway kilometers and reduced unemployment rate are part of the Corridor IV of the pan European transport corridors, one of the most important routes, which passes through Constanta, Bucuresti, Pitesti, Sibiu, Lugoj, Timisoara, Arad and Nadlac, all of them being part of cluster 0.

Thanks to a clustering approach, the Romanian counties have been grouped based on similar net salaries, unemployment rate, number of tourists, highway kilometers and electrified kilometers of railway, resulting two groups, one which has a higher kilometers of railway and highway, a higher net salary, with multiple tourists and less unemployment rate, while the second cluster includes the counties with least development, having a higher unemployment rate and a reduce electrified kilometers of railway, highway, less tourists and a smaller net salary.

Based on the observations made regarding the two formed clusters, some policy recommendations should be made, especially for the counties included in cluster 1. First, the interested parties should prioritize more the investment in highway and electrified railway infrastructure, develop regional and local transport networks which facilitate the labor mobility and the expansion of the business environment, and maximize the use of European Union structural funds in transportation infrastructure in order to reduce the regional disparities. Furthermore, investment incentives and economic diversification could be considered. In this manner, private investment can be properly attracted, industrial parks can be created, with direct effect on the economic growth. Regional tourism should be better promoted by investing in marketing and infrastructure for local tourist attractions, including cultural heritage, natural parks, and rural tourism. In terms of workforce development, a series of actions could be considered, such as, but not limited to: creating training programs tailored for the local economic needs, provide incentives for the companies to allow remote work which could reduce the need for skilled works to migrate, and encourage young professionals to remain in their home counties through the development of specific programs that encourage these actions.

The future research should focus on the prediction of net salaries of each county based on unemployment rate, highway kilometers, electrified kilometers of railway, number of tourists and other indicators such as inflation rate or GDP per county, in order to see the main features that influence the net salaries evolution. On the same time, a more detailed analysis of regional development of Romanian counties will be performed, exploring human development index or education level.

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