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Sustainable Healthcare Development in Romania: Comparative Cluster Analysis of Hospitalisation Indicators from 2019 and 2023 Highlighting Regional Disparities

Abstract. *This study analyses hospitalisation services for acute and chronic patients in Romania, comparing data from 2019 and 2023. Using K-means clustering and the analysis of variance (ANOVA) on data from the National Institute for Health Services Management, the research identifies and compares regional clusters based on hospitalisation indicators and socio-demographic variables. The results for 2019 indicate the presence of four clusters that highlight regional disparities in terms of hospitalisation patterns. Bucharest is part of its own cluster, suggesting its distinct health infrastructure, taking into consideration that this is the capital of the country, being the most developed area, with the greatest potential, but also unique problems. In 2023, there were three main clusters indicating of a possible reduction in disparities when it comes to hospitalisation services at the county level. The results also show that there were significant variations among the groups with respect to insured cases, age distribution, and rural-urban divide. These findings show that public health policies should be carefully designed to address these regional disparities and ensure equitable access to healthcare for everyone.*

Keywords: *hospitalisation, sociodemographic determinants, sustainable development, regional disparities, cluster analysis, SARS-CoV-2 pandemic.*

JEL Classification: I18, R10, Q01.

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1. Introduction

Various healthcare systems all over the world face complicated issues which have social, ecological, and economic aspects that put at risk their sustainability in the long run. One of the most intricate problems concerning sustainable development in Romania is related to differences in access to healthcare services among different regions. As a result, this must be accounted for when formulating health policies at the county level so that it can foster equitable growth and reduce disparities across regions irrespective of their socioeconomic status.

The objective of this paper is to analyse data on hospitalisation services for acute and chronic patients in Romania for 2019 and 2023 in order to reveal various patterns. Using the K-means clustering technique in conjunction with the ANOVA method, this research aims to identify various regional groups based on hospitalisation indicators and to compare them based on sociodemographic variables.

The dataset was obtained from Diagnosis Related Groups (DRG) national database managed by National Institute for Health Services Management and it includes several hospital indicators at the county level, such as the number of acute and chronic cases, the number of hospitalisation days, and the average length of stay. Sociodemographic variables like insurance coverage, age distribution, and urban-rural residency were also included in the analysis.

The results of this study are expected to bring to light the potential imbalances that exist at the level of the Romanian healthcare system. The goal is to determine the areas where improvements are needed to promote sustainable development and reduce inequalities.

The following sections will provide a review of the existing literature regarding sustainable healthcare and regional disparities, detail the data and research methodology, and last but not least, present the analysis results and the implications of the findings. The paper will conclude by summarising the key contributions and offering suggestions for future research.

2. Review of the scientific literature

Globally, discussions about the healthcare system increasingly focus on sustainability as a concept. Sustainable healthcare is the effective use of resources to minimise environmental harm and, by maximising access to care, promote health fairness. To achieve these goals, it is crucial to analyse regional disparities in hospitalisation data along with sociodemographic factors.

Growing interest in sustainable healthcare

In recent years, there have been more and more discussions about developing sustainable healthcare systems, considering the increasing challenges associated with their impact on the environment. In this regard, the World Health Organisation has recently released a strategic plan that emphasises sustainable health systems, which

aims to manage resources efficiently, reduce waste, and reduce greenhouse gas emissions (WHO, 2017). Moreover, the Joint Commission has highlighted the importance of healthcare systems being ready for environmental problems and also climate effects on health equity (Joint Commission, 2024).

In addition, The American College of Healthcare Executives (ACHE) has provided a framework for designing sustainable hospitals that incorporate economic, environmental, and social sustainability pillars. They underline the need for hospitals to put more emphasis on prioritising vital treatment, simplifying healthcare services, and flexible long-term planning to reduce the impact on the environment (ACHE, 2024).

Importance of analysing regional disparities

Explaining regional inequalities in healthcare is essential for the formulation of specific policies so that the distribution of medical services is uniform. Thus, in a research that analyses inequalities in public health systems in Romania, Cristache et al. (2019) discovered considerable geographical discrepancies in the provision of health services, which were linked to reasons such as insufficient medical staff and lack of cutting-edge technology in some areas. Also, according to Damian et al. (2022), there are significant differences between urban and rural areas regarding the number of physicians and medical facilities, with large urban centres having a higher concentration of healthcare resources. These disparities result in a reduced availability of medical services in rural areas or cities with smaller populations, underlining the need to focus on improving the health infrastructure in underserved areas in order to reduce inequalities. Last but not least, Nae and Panie (2020) mention a vicious circle present in the COVID-19 crisis, as the pandemic affects inequalities while growing inequalities cause the virus to spread, undermining economic recovery efforts.

Sociodemographic factors in healthcare utilisation

Sociodemographic characteristics are important determinants that can significantly influence the use of hospitalisation services and the sustainability of health systems. Therefore, understanding these factors is essential to create equitable and sustainable healthcare systems. A study about determinants of medicine use in Romania revealed the impact of socio-economic and health behaviour factors on the use of prescribed and self-prescribed medicines, indicating significant inequalities within different age groups (Jemna et al., 2021).

Another important aspect of sustainable healthcare refers to the extent to which healthcare services can be accessed from a geographical point of view. A research utilising real-time traffic data on the health system in Romania highlighted significant geographical variations in terms of the degree of accessibility of hospitals (Dumitrache et al., 2020). These results actually underline the need for strategic placement of hospital units to ensure equitable access to medical services.

Moreover, a study carried out to compare the general population and Roma communities in Romania found that there are sociodemographic inequalities regarding the use of hospital services (Olariu et al., 2019). It follows that efforts should be

directed towards the formulation of health policies that ensure the inclusion of individuals and the reduction of these variations, in order to improve the quality of life.

Impact of the COVID-19 pandemic on healthcare sustainability

The COVID-19 pandemic has deeply influenced the health systems of various countries worldwide, revealing their weaknesses as well as difficulties they face in achieving sustainable development (Pamučar et al., 2020; Bălășoiu, 2021). This crisis put enormous pressure on healthcare providers and highlighted the importance of a solid and adaptable healthcare system for pandemics such as this one (Mobasher, 2022).

As Berger et al. (2021) noted, there was an increase in hospital admission and intensive care units (ICU) utilisation due to COVID-19 pandemic that strained health resources and infrastructure. This underlined the need for early response and improvement in health infrastructure to ensure the resilience of health systems. The implementation of lockdowns and other non-pharmaceutical interventions during this period have proven highly effective in slowing the transmission of COVID-19, as well as in reducing the number of hospitalisation cases. These measures clearly demonstrated the critical role of public health interventions in maintaining the sustainability of healthcare systems (Flaxman et al., 2020). Also, the pandemic led to increased costs and decreased profitability for hospitals, especially in Eastern Europe (Naruć, 2022). This financial burden underscored the importance of sustainable economic policies within healthcare systems to manage future crises properly.

Sustainable healthcare development

When it comes to health, sustainable development is defined as the incorporation of environmental, economic, and social factors in order to ensure that health services are both fair and effective (Bușu and Fonseca, 2020). Sustainable hospitals in particular refer to those facilities that minimise their impact on the environment, by embracing energy efficient technologies and adopting vast management strategies (Annura et al., 2022).

The Sustainable Development Goals (SDGs) work as a compass for guiding global priorities in terms of sustainable development and target health-related problems, as well as social and environmental problems. They cover 17 goals aimed at tackling issues such as poverty reduction and ending hunger, better education and healthcare, reduced inequalities, access to clean water supply and energy, ensuring fairness in society, protecting the environment, and addressing climate change. However, the SDGs do not include priorities related to primary health care (PHC), which is a tool for reshaping health systems, building more robust inter-sectoral policies and ensuring a more equitable society (Hone et al., 2018). According to Stere et al. (2023), for the effective implementation of the Sustainable Development Goals in Romania, an integrated approach at the local and regional level is needed, these objectives being evaluated using different indicators from various fields, such as economy, energy, education, and health.

Finally, to be sustainable, health systems must address both environmental issues and inequalities between individuals regarding their access to health services. Furthermore, understanding and integrating sociodemographic characteristics allows health systems to adopt more specific strategies in order to ensure long-term sustainability. This comprehensive strategy is critical to building healthier communities and a more resilient healthcare system.

3. Data and methodology

3.1 Data

The dataset from the National Institute for Health Services Management - Diagnosis Related Groups (DRG) national database includes seven hospital indicators for each county: acute cases, hospitalisation days for acute cases, average length of stay for acute cases, case mix index, chronic cases, hospitalisation days for chronic cases, and average length of stay for chronic cases. To investigate the diversity in continuous hospital services at the county level using a population-based approach, the dataset also includes eleven sociodemographic variables from 2019: insured cases percentage, cases percentage from the same county, cases percentage by age groups (0-4, 5-17, 18-44, 45-65, over 65), female cases percentage, male cases percentage, and cases percentage from urban and rural areas. The dataset contains variables for the years 2019 and 2023 in order to highlight the way in which the population at the county level has utilised continuous hospitalisation services (both acute and chronic) during this period, marked by the effects of the COVID-19 pandemic.

In order to ensure the results are accurate and relevant as possible, the variables were standardised before the clustering process. Standardisation is an important pre-processing step in data analysis because it ensures that each variable contributes equally to the clustering process by rescaling the data to have a zero mean and one standard deviation.

The research methodology involves two main steps, namely clustering using the K-means technique based on several hospital indicators, followed by the comparison of the clusters obtained using ANOVA based on sociodemographic indicators.

3.2 K-means clustering

Sinaga and Yang (2020) defined K-means clustering as a widely adopted method for grouping data points according to their characteristics while minimising variation within clusters. The algorithm iteratively processes the centre of the clusters and reassigns points to the clusters based on the shortest distance to the centres. Further research has been done on the K-means clustering algorithm and different extensions have been proposed in the literature (Alhawarat and Hegazi, 2018; Meng et al., 2018; Lv et al., 2019; Zhuet al., 2019). The methodology implies four main steps, as follows:

• **Initialisation:** Involves selecting the number of clusters, k and the random initialisation of the centroids $\mu_1, \mu_2, \mu_3, \dots, \mu_k$.

• **Assignment step:** In this step, each data point x_i is assigned to the nearest centroid based on the Euclidean distance, which is the straight-line distance between any two points, using the following equation:

$$C_i = arg\ min\ _j \|x_i - \mu_j\|^2 \quad (1)$$

where:

C_i is the cluster assignment for data point x_i, and μ_j is the centroid of cluster j.

• **Update step:** Involves the recalculation of the centroids as the mean of all points assigned to each cluster. The updated centroid j for cluster j is computed as:

$$\mu_j = \frac{1}{|C_j|} \sum_{x_i \epsilon C_j} x_i \quad (2)$$

where:

$|C_j|$ is the number of points in cluster j, and the sum is overall all points x_i assigned to cluster j.

• **Converge:** Involves repeating the assignment and update steps until the centroids of the clusters no longer change or the change is below a certain defined threshold.

Among the most common ways to find the number of clusters for the K-means technique are the Elbow method, which involves finding the inflection point where the sum of the squared distances decreases significantly; the silhouette score, which measures clustering quality by finding a trade-off between variability between groups and within groups; and trial and error, in which different values of k are tried out, and meaningful clusters are seen.

3.3 Anova analysis

ANOVA (Analysis of Variance) is a statistical technique that is used for comparing means between several groups for the purpose of finding out if there are any statistically significant differences between these group means. The null hypothesis (H_0) assumes that all cluster means are equal, while the alternative hypothesis (H_1) states that at least one mean of the clusters differs. To proceed, one calculates the mean of each cluster ($\overline{x_j}$) and the overall mean ($\bar{x}$).

The next step involves calculating the sum of squares. The Between-Groups Sum of Squares (SSB) is given by:

$$SSB = \sum_{j=1}^{k} n_j \left(\overline{x_j} - \bar{x}\right)^2 \quad (3)$$

where n_j is the number of observations in cluster j. The Within-Cluster Sum of Squares (SSW) is:

$$SSW = \sum_{j=1}^{k} \sum_{i=1}^{n_j} (x_{ij} - \bar{x})^2 \quad (4)$$

where x_{ij} is the i-th observation in cluster j.

Finally, the F-statistic is computed using the formula:

$$F = \frac{SSB/(k-1)}{SSW(N-k)} \quad (5)$$

where: k is the number of clusters and N is the total number of observations. After, the F-statistic is compared with the critical value for that particular degree of freedom which is obtained from the F-distribution. This technique has found common use across different fields such as social sciences, medical research, and experimental design (Ntumi, 2021; Schober and Vetter, 2020), thereby providing a holistic approach to data analysis.

4. Results and discussion

2019

The K-means algorithm was first applied to the data from 2019. According to the elbow graph (Figure 1), the optimal number of clusters was identified as 2, separating Bucharest from the other counties.

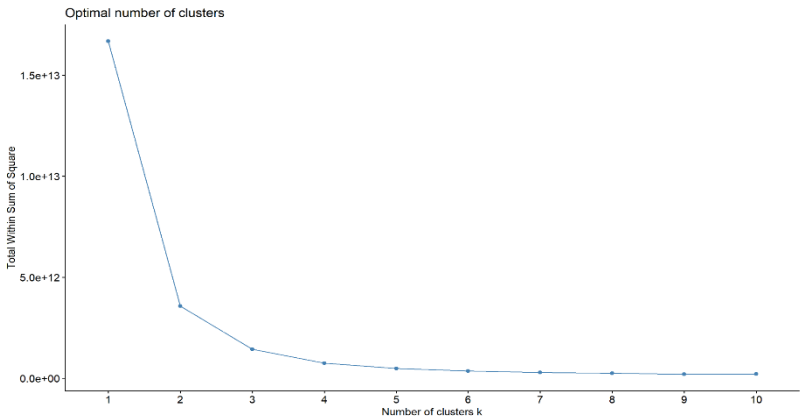

Figure 1. Optimal number of clusters using elbow for 2019 data
Source: Author's processing in R.

However, to ensure the interpretability of the results, the K-means procedure was also tested with 3 and 4 clusters. Based on the silhouette score (Appendix A), which measures how well-separated and compact the clusters are, the accuracy of the clustering was found to be better with 4 clusters. Thus, Figure 2 presents the

counties of Romania grouped into 4 clusters for the year 2019, providing a more detailed and accurate representation of regional variations in continuous hospitalisation services.

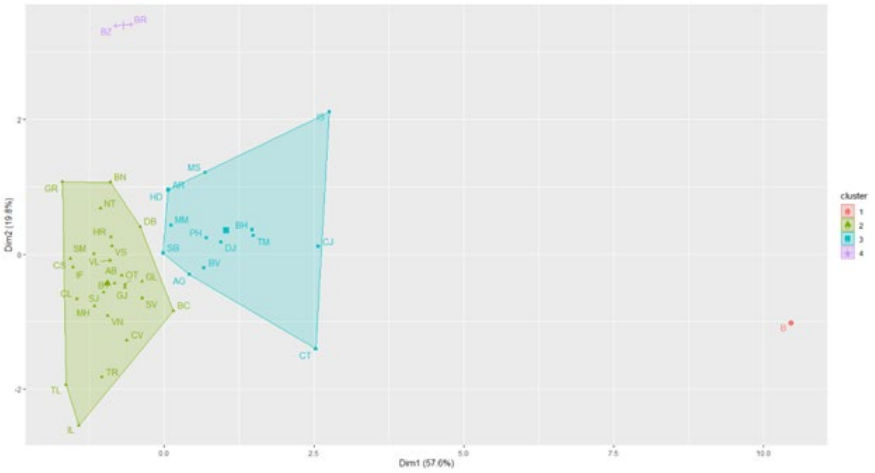

Figure 2. K-means clustering for 2019 data

Source: Author's processing in R.

The cluster plot for 2019 presents the Romanian counties grouped into four distinct clusters based on hospitalisation indicators.

Bucharest (B) forms a cluster of its own, highlighting particular hospitalisation trends compared to the rest of the counties, which can be attributed to its state as the country's capital. This area has a considerable population density and modern medical units, as well as specialised medical assistance services. Also, being a capital city, Bucharest has unique challenges, such as resource allocation and the oversupply of sustainable medical services.

The green cluster includes various counties like Gorj (GR), Neamț (NT), Harghita (HR), Satu Mare (SM), Sălaj (SJ), etc. These regions have an average quality health infrastructure and moderate population densities. Considering this, the counties from the green cluser could focus more on improving healthcare access by investing in local medical infrastructure to reduce pressure on more developed centres.

The blue cluster contains significant counties such as Cluj (CJ), Iași (IS), Constanța (CT), Brașov (BV), Timiș (TM), Mureș (MS), etc. This cluster mostly includes counties with universities of medicine and, hence, better healthcare infrastructure and resources. These regions actually benefit because the educational institutions contribute to the sustainable development of health services through research, innovation, and constant training of professionals in this field.

Finally, the purple cluster only includes Buzău (BZ) and Brăila (BR), indicating their distinctive healthcare patterns.

The clusters that resulted were then subjected to analysis of variance (ANOVA) based on key sociodemographic variables. By analysing the distribution of the clusters, the research aimed to find further patterns explaining regional disparities. The results,

presented in Table 1, revealed significant disparities among the clusters in terms of multiple demographic variables.

Table 1. ANOVA analysis for 2019

Variable	Average values				
	Cluster 1 N=1	Cluster 2 N=25	Cluster 3 N=14	Cluster 4 N=2	p-value
% Insured cases	98.4	96.0	97.8	96.0	0.005
% Cases from the same county	44.7	95.2	85.2	94.1	0.007
% Cases age 0-4	9.69	10.6	11.2	9.52	0.581
% Cases age 5-17	6.62	6.36	7.12	6.03	0.470
% Cases age 18-44	20.5	17.7	18.2	18.6	0.462
% Cases age 45-65	32.4	28.6	30.7	29.9	0.084
% Cases aged over 65	30.8	35.9	33.1	36.0	0.053
% Female cases	44.4	45.8	45.7	47.0	0.274
% Male cases	55.6	54.2	54.3	53.0	0.274
% Urban cases	68.7	42.0	52.1	49.1	0.002
% Rural cases	31.3	58.0	47.9	50.9	0.002

Source: Author's processing in R.

The results indicate that there are major differences between the clusters in terms of insured cases, with cluster 1 (Bucharest) having the largest number of insured patients at 98.4%, then clusters 2 and 4 have the lowest (96.0%). High levels of insurance coverage in Bucharest might mean increased availability of healthcare services, which could lead to a sustainable health system over time. Additionally, there is a significant difference in the percentage of cases treated within the same county. Cluster 1 (Bucharest) has the lowest percentage (44.7%), suggesting that there is a significant number of patients transferred from other counties and implicitly associated environmental impacts. Hospitalisation rates for middle-aged patients (45-65) and elderly persons (65 and over) were significantly low in cluster 1 (Bucharest), this might be due to well-developed preventive care system and management of chronic diseases. Besides, there is a great discrepancy between urban and rural accessibility in health care. The development of the healthcare infrastructure in rural areas is necessary for sustainable growth that would also lead to equal access to healthcare rather than overwhelming urban health facilities.

2023

In a similar manner, the analysis was conducted for the year 2023. The elbow plot for this year, shown in Figure 3, suggested an optimal number of two clusters, specifically distinguishing between Bucharest and the rest of the counties.

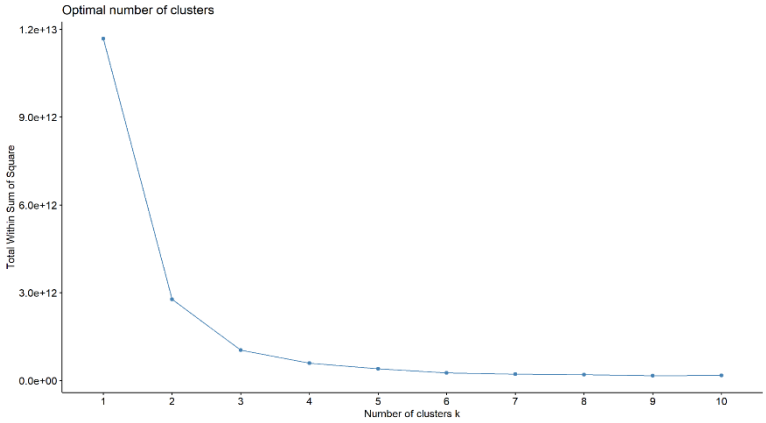

Figure 3. Optimal number of clusters using elbow for 2023 data
Source: Author's processing in R.

However, to achieve a more comprehensive interpretation, the K-means clustering procedure was also tested with 3 and 4 clusters. Upon further evaluation using the silhouette method (Appendix A), it was established that using 3 clusters provides a preferable solution. Thus, the results obtained from this analysis are presented in Figure 4.

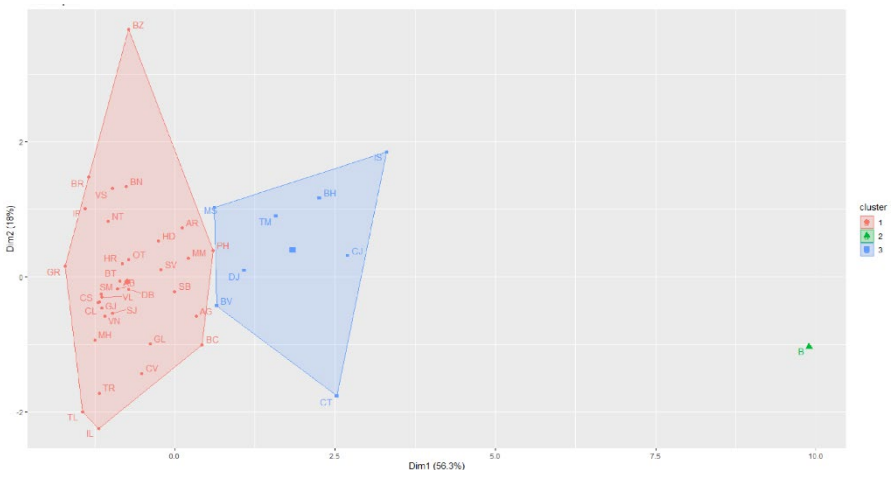

Figure 4. K-means clustering for 2023 data
Source: Author's processing in R.

The formation of three different clusters is shown in the 2023 cluster plot, which categorises counties based on hospitalisation indicators.

The green cluster only consists of Bucharest, highlighting its unique healthcare dynamics, which are driven by advanced medical facilities, high population density, and a large number of inpatients.

The blue cluster includes mainly counties with medical universities, such as Cluj (CJ), Iași (IS), Mureș (MS), Timiș (TM), Brașov (BV), and Constanța (CT). The presence of medical universities in these counties suggests a better healthcare infrastructure and a steady flow of medical professionals, contributing to superior healthcare services and outcomes.

Finally, the red cluster contains different counties like Buzău (BZ), Tulcea (TL), Bacău (BC), among others. These counties are probably having medium to low medical resources when compared with those that have university centres. Hence it is essential to improve health units' state and remove barriers to accessing medical facilities in these areas, by investing in local healthcare infrastructure as well as health programs that would enhance the development of a sustainable health system.

While in 2019, there were four clusters, in 2023, there were three main clusters, suggesting a potential reduction in the use of inpatient services at the county level. One possible reason for this change is better access to healthcare. Over the years, effective health policy and equitable resource allocation might have reduced large disparities by combining previously disparate groups. Additionally, there could be some changes in population dynamics such as urbanisation and emigration that might have affected health care needs and service utilisation impacting cluster formation.

Next, to compare the clusters grouped on the basis of hospitalisation indicators using demographic indicators, the ANOVA procedure was employed. The results, presented in Table 2, provide information on demographic characteristics that can influence hospitalisation patterns and highlight the distinct profiles of each group.

Table 2. ANOVA analysis for 2023

Variable	Average values			
	Cluster 1 N=33	**Cluster 2 N=1**	**Cluster 3 N=8**	**p-value**
% Insured cases	96.2	98.5	97.6	0.151
% Cases from the same county	93.5	43.9	75.4	<0.001
% Cases age 0-4	10.1	9.07	10.8	0.354
% Cases age 5-17	5.92	7.32	7.46	0.029
% Cases age 18-44	17.0	19.6	18.1	0.150
% Cases age 45-65	29.3	31.0	29.8	0.578
% Cases age over 65	37.4	33.0	34.5	0.011
% Female cases	46.3	45.0	46.5	0.581
% Male cases	53.7	55.0	53.5	0.581
% Urban cases	56.5	32.3	47.7	0.015
% Rural cases	43.5	67.7	52.3	0.015

Source: Author's processing in R.

The table shows that the percentage of patients treated within the same county varies significantly among clusters. Clusters 2 and 3 have lower percentages, indicating strong healthcare infrastructures that cause patients from other counties to depend on them. The increased hospitalisation rates for those aged 5 to 17 in clusters 2 and 3 may reflect unique healthcare requirements or gaps. Like the results for the year 2019, there is significant variation in hospitalisation rates among individuals aged 65 years and above. The largest percentage is in cluster one (37.4%), while cluster two has the lowest figure of hospitalisation rate of 33.0%. Therefore, sustainable healthcare practices must focus on prevention and home-based care services to manage this population effectively and minimise the burden on hospitals. Not least, there are major disparities in the distribution of urban and rural cases. Cluster 1 shows a balanced mix of 56.5% urban and 43.5% rural cases. Cluster 2 (Bucharest) is largely urban (32.3% urban, 67.7% rural), whereas cluster 3 has 47.7% urban and 52.3% rural.

5. Conclusions

There is a need for the world to address environmental, economic, and social approaches in order to achieve sustainable healthcare systems. In Romania, it is important to recognise that addressing inequality in access to healthcare across regions is critical to achieving equitable outcomes in health. This research work examined hospitalisation services for both acute and chronic patients by evaluating data from 2019 and 2023, revealing regional variations and highlighting the need for focused policy interventions.

From the analysis, it was found that hospitalisation patterns in Romania differ considerably between regions. In 2019, there were four distinct clusters, with Bucharest forming a separate cluster due to a more robust healthcare infrastructure. In 2023, there were three main clusters, suggesting a potential reduction in regional disparities. The research identified notable variances in insured instances, age categories, and urban-rural breakdown within the clusters. These differences underscore how sociodemographic factors play a crucial role in healthcare usage and results.

The results underscored the importance of specific adjustments to healthcare systems, especially in areas with few service provisions. Development of health infrastructure and ensuring equal access to healthcare are prerequisites for sustainable development in these regions. The research also highlights the need for resilient and adaptive health systems mostly due to the COVID-19 pandemic.

Other socioeconomic factors that can be included in future studies would be income, education level, or work position, which would give a better picture of health care services differences. The analysis of how specific policies and interventions have impacted regional disparities could also provide valuable learning on how to promote long-term growth in healthcare industry.

In conclusion, this study underscores the significance of certain health strategies targeting regional disparities in Romania. The existing healthcare system could be

made better by policymakers to develop more sustainable health care growth, fair medical services, and an upgraded sector infrastructure. This holistic approach is critical to enabling long-term resilience and equity within the health system, which eventually would result in a healthy population.

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Appendix A

Evaluating clustering for 2019 and 2023 using silhouette

Year	Number of clusters	Average silhouette width
2019	2	0.74
	3	0.25
	4	0.3
2023	2	0.72
	3	0.34
	4	0.2