

Jenčová, Sylvia; Vašaničová, Petra; Miškuřová, Marta

## Article

# Comprehensive assessment of slovakian hospitals using financial and non-financial criteria in the COVID-19 context

Economies

## Provided in Cooperation with:

MDPI – Multidisciplinary Digital Publishing Institute, Basel

*Suggested Citation:* Jenčová, Sylvia; Vašaničová, Petra; Miškuřová, Marta (2024) : Comprehensive assessment of slovakian hospitals using financial and non-financial criteria in the COVID-19 context, *Economies*, ISSN 2227-7099, MDPI, Basel, Vol. 12, Iss. 9, pp. 1-22, <https://doi.org/10.3390/economies12090255>

This Version is available at:

<https://hdl.handle.net/10419/329182>

## Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

## Terms of use:

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<https://creativecommons.org/licenses/by/4.0/>

## Article

# Comprehensive Assessment of Slovakian Hospitals Using Financial and Non-Financial Criteria in the COVID-19 Context

Sylvia Jenčová, Petra Vašaničová \*  and Marta Miškuřová 

Faculty of Management and Business, University of Prešov, 080 01 Prešov, Slovakia; sylvia.jencova@unipo.sk (S.J.); marta.miskufova@unipo.sk (M.M.)

\* Correspondence: petra.vasanicova@unipo.sk

**Abstract:** Comparing hospitals using multicriteria methods facilitates a thorough assessment of performance across multiple dimensions, supports informed decision-making, promotes accountability, and drives continuous improvement in healthcare delivery. This paper aims to apply multicriteria methods to assess hospitals in Slovakia in the pre-crisis (2019), crisis (2021), and post-crisis (2023) periods of the COVID-19 pandemic. The assessment is conducted using four multicriteria methods, i.e., a ranking method, scoring method, normed variable method, and TOPSIS method, and nonmetric multidimensional scaling (NMDS). The research sample comprises a group of hospitals classified under the sector (SK) NACE 86.1—Hospital activities. Seven indicators (financial and non-financial) were entered into the analysis. The results show that the agreement among the employed multicriteria evaluation methods was statistically significant. Moreover, the findings demonstrate that Slovak hospital rankings based on the selected criteria vary over time. The perfect quality of the NMDS models, as indicated by stress values below 0.025, shows that NMDS analysis provides a highly accurate and reliable representation of hospital comparisons. By combining multicriteria methods with NMDS, we harness the strengths of each approach to improve decision-making and achieve greater insights into intricate datasets. A comprehensive assessment of hospitals allows for the identification of the system's strengths and weaknesses, which can be utilized to formulate new improvement strategies. As an additional benefit, this paper includes a bibliometric analysis, offering a systematic evaluation and synthesis of existing research on multicriteria evaluation methods.

**Keywords:** hospital; healthcare; multicriteria evaluation; multidimensional scaling; COVID-19; financial management



**Citation:** Jenčová, Sylvia, Petra Vašaničová, and Marta Miškuřová. 2024. Comprehensive Assessment of Slovakian Hospitals Using Financial and Non-Financial Criteria in the COVID-19 Context. *Economics* 12: 255. <https://doi.org/10.3390/economics12090255>

Academic Editor: Angeliki N. Menegaki

Received: 16 July 2024

Revised: 3 September 2024

Accepted: 19 September 2024

Published: 21 September 2024



**Copyright:** © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

Healthcare is one of the most closely monitored aspects of human activity due to its critical impact on individual and public health, economic stability, and social well-being. Porter and Lee (2013) stated that monitoring includes tracking health outcomes, patient safety, resource allocation, and adherence to best practices and regulations. Advances in technology, data analytics, and policy reforms continuously shape the way healthcare is delivered and evaluated, aiming to improve health outcomes and reduce disparities. According to Li et al. (2023), the COVID-19 pandemic has had a profound impact on the operations, expenditures, and income of hospitals.

While the healthcare system plays a crucial role in managing public health, the intrinsic value of health at an individual level underscores the importance of these efforts (Moss et al. 2023). Health is an individual's most precious asset, whose worth is immeasurable despite the numerous methods available to measure it (Murphy and Topel 2006). A prevalent characteristic of its functioning is the widespread perception of financial resource scarcity, whether in the most developed or developing countries. One of the fundamental objectives of the healthcare system is to ensure the health and well-being of individuals. Health literacy is essential for life, serves as a core function of the health system, constitutes a vital

component of social capital, holds undeniable economic value, and remains a top priority (Sørensen et al. 2015).

Hospitals, as essential frontline entities, have faced ongoing challenges in navigating the effects of the COVID-19 pandemic (Rhodes et al. 2023). The COVID-19 pandemic has significantly increased the demand for medical services, placing an unprecedented burden on healthcare systems (Ardakani et al. 2023). A thorough evaluation of hospitals helps identify system strengths and weaknesses, aiding in developing new improvement strategies.

This paper aims to apply multicriteria methods to assess hospitals in Slovakia in the pre-crisis (2019), crisis (2021), and post-crisis (2023) periods of the COVID-19 pandemic. The research sample consists of a set of hospitals in the sector (SK) NACE 86.1—Hospital activities. The evaluation is carried out based on four multicriteria methods, i.e., a ranking method, scoring method, normed variable method, and TOPSIS method, and nonmetric multidimensional scaling (NMDS). Three objectives follow from the aim of this paper. The first objective is to determine whether the four multicriteria evaluation methods provide consistent rankings of hospitals. The second objective is to assess whether hospital rankings shift over time (pre-crisis, crisis, and post-crisis periods of the COVID-19 pandemic). The third objective is to determine whether the distances between hospitals in the original high-dimensional space will be preserved in the two-dimensional space. By integrating multicriteria methods with multidimensional scaling (MDS), we leverage the strengths of both approaches to enhance the overall decision-making process and gain deeper insights into complex datasets. As is presented by Rahimi et al. (2014), the precise selection of indicators has an impact on improving the quality of services and assessment accuracy.

Our findings contribute to the existing research and fill the research gap by examining Slovak hospital evaluations. The selection of financial and non-financial indicators forms an essential part of the qualitative assessment of decision units in space. The contribution of this research is the analysis of the financial and non-financial indicators that are most used in the evaluation of hospitals. The most important is the assessment and insight into the competitiveness of individual hospitals in the analyzed sector using multicriteria evaluation methods and the comparison of individual results. Another contribution is a theoretical look at the position of public and private hospitals in the pre-crisis, crisis, and post-crisis periods of the COVID-19 pandemic in the structure of the Slovak economy. Its contribution is to broaden the knowledge base of multicriteria methods in the financial management context. Knowing the financial position of hospitals and responding to problems promptly can increase not only a hospital's viability but also its competitiveness and position in the space. This analysis can help in practical applications in future research papers in the field of healthcare economics and management.

The remainder of this paper is organized as follows. Section 2 provides the literature review. Section 3 presents data and methods. Section 4 provides the results, including visualization from NMDS and the rankings derived from the multicriteria evaluation. Section 5 discusses the findings, and Section 6 concludes the paper.

## 2. Literature Review

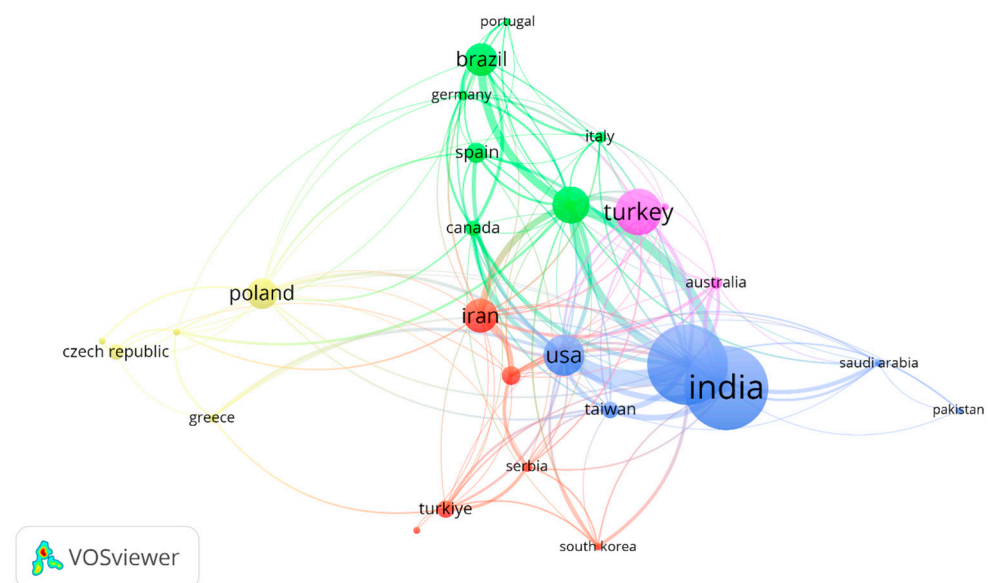
The financial management of a healthcare organization is the process of providing an overview of the day-to-day financial operations and planning the long-term financial flows of the organization (Jakušová 2016). Financial decisions at both the operational and strategic levels encompass multidimensional aspects that manifest in various ways (Zopounidis et al. 2015). The assessment of financial credibility in the Slovak healthcare sector has been the subject of research by Petruška et al. (2019) and Štefko et al. (2017).

Financial management involves selecting the best options for acquiring internal and external financing sources and utilizing them to achieve the fundamental financial goals of the business (Raipuria 2020). In financial management, it is crucial to employ various approaches for evaluating financial status, enabling the use of multiple criteria to assess any given situation (Baydaş et al. 2022; Türegün 2022). Multicriteria methods are usually used to evaluate and rank alternatives based on multiple criteria (Pamučar et al. 2017). They

help in making decisions where multiple factors need to be considered simultaneously (Ceballos et al. 2016). MDS is a technique used for visualizing the similarity or dissimilarity of data in a low-dimensional space (Saeed et al. 2018). It helps in identifying patterns or clusters within the data.

In this section, we provide a bibliometric analysis, a powerful tool for systematically evaluating and synthesizing existing research on the presented topic, i.e., multicriteria evaluation methods. Publications exported from the Web of Science database were input into the bibliometric analysis. A query command for the Topic option was entered into the search bar using the Boolean “OR” operator in the following structure: “multicriteria methods” OR “normed variable method” OR “TOPSIS” OR “multidimensional scaling” OR “MDS”. Only the most recent research publications from 2018 to 2024 within the categories of Economics, Management, Business, and Business Finance were included. After the above limitations, the input to the bibliometric analysis consisted of 1150 publications. Bibliometric maps were created using VOSviewer.

First, the analysis focused on examining which countries/regions have addressed the issue. A country/region was considered for analysis only if it had a minimum of 10 publications affiliated with it on the topic. Figure 1 contains the constructed bibliometric map that classified the five color-coded clusters of the 27 collaborating countries/regions. A higher point on the map represents a larger contribution of the country/region to the issue. India, the USA, Turkey, Iran, and Brazil are among the countries/regions exerting the most significant influence. Thicker links between countries/regions mean more frequent cooperation. Table 1 shows the classification of countries/regions into clusters.



**Figure 1.** Bibliometric map of country/region occurrence. Source: own processing in VOSviewer.

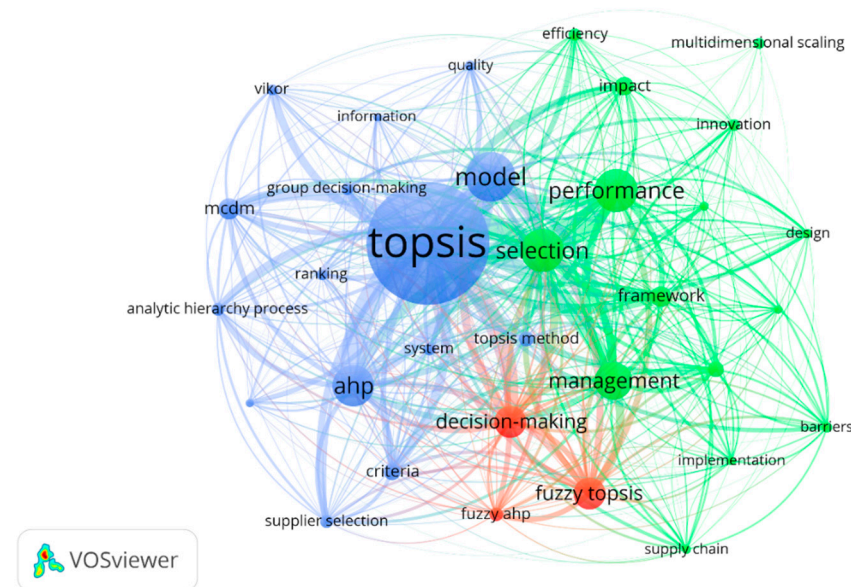
Another part of the bibliometric analysis involves examining the occurrence of keywords within a given field. A keyword was included if it occurred at least 30 times in the underlying publications. Figure 2 offers a generated bibliometric map that classifies the three color-coded clusters (see also in Table 2). A higher point on the map represents a more frequent occurrence of a keyword, and a thicker link between keywords means their more frequent occurrence together in publications.

Figure 3 presents the most frequently mentioned keywords in the publications analyzed, specifically using density visualization. The greater the reach of the keyword, the greater the content of the colored area around that particular keyword. TOPSIS, model, performance, selection, AHP, and management are among the most discussed keywords.

**Table 1.** Classification of countries/regions into clusters.

Cluster	Color	Countries/Regions
1	Green	Brazil, Canada, England, Germany, Italy, Portugal, Spain
2	Blue	India, Pakistan, China, Saudi Arabia, Taiwan, the USA
3	Red	Indonesia, Iran, Lithuania, Serbia, South Korea, Turkey
4	Yellow	Czech Republic, France, Greece, Poland, Slovakia
5	Violet	Australia, Malaysia, Turkey

Source: own processing according to VOSviewer.

**Figure 2.** Bibliometric map of keywords occurrence. Source: own processing in VOSviewer.**Table 2.** Classification of keywords into clusters.

Cluster	Color	Keywords
1	Green	barriers, design, efficiency, framework, impact, implementation, industry, innovation, management, multidimensional scaling, performance, selection, supply chain, supply chain management, sustainability
2	Blue	AHP, analytic hierarchy process, criteria, group decision-making, information, MCDM, model, multicriteria decision-making, quality, ranking, supplier selection, system, TOPSIS, TOPSIS method, VIKOR
3	Red	decision-making, fuzzy AHP, fuzzy TOPSIS

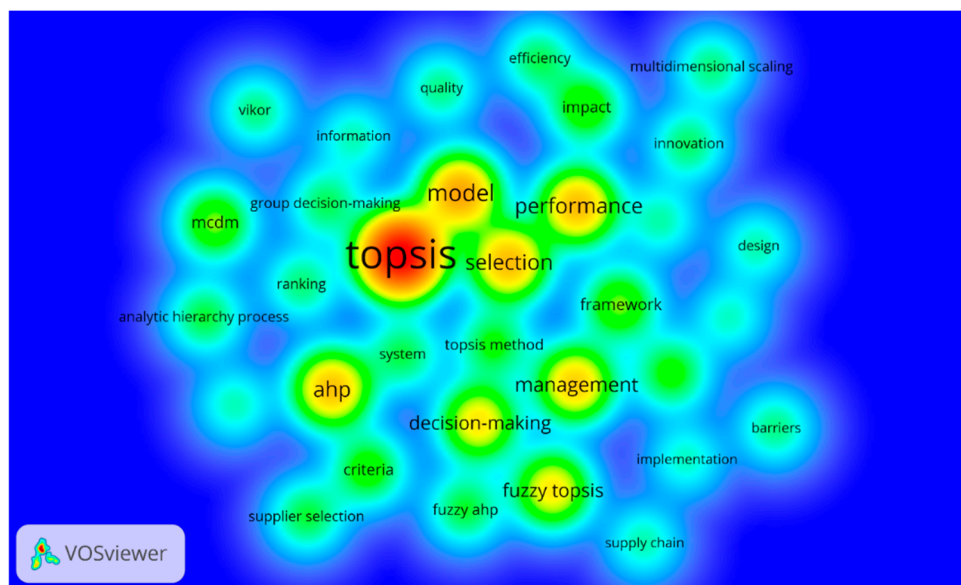
Source: own processing according to VOSviewer.

A systematic approach to addressing complex planning and decision-making issues requires a careful balance between comprehensive detail and limited information. The outcomes of an evaluation process need to be conveyed to policymakers in a practical and understandable form, especially considering that evaluation issues typically involve multiple dimensions (Nijkamp et al. 2013). Multicriteria evaluation aims to provide a structured approach to evaluate different options and rank them based on their performance against the criteria (Proctor and Drechsler 2006).

Multicriteria methods are often based on elementary characteristics, e.g., arithmetic mean, variance, standard deviation, and coefficient of variation (Jenčová 2018). The TOPSIS (Technique for Order Preference and Similarity to Ideal Solution) method is widely recognized as one of the most precise multicriteria evaluation methods. The method operates on the principle that the best alternative should have the least geometric distance from a positive-ideal solution. The general approach includes comparing various alternatives



by assigning weights to each evaluation criterion, normalizing the scores obtained, and subsequently calculating the Euclidean distance from an ideal solution (Thakkar 2021).



**Figure 3.** Bibliometric map of the most discussed keywords. Source: own processing in VOSviewer.

Several multicriteria evaluation methods can produce varying outcomes due to their unique approaches in weighting criteria, handling uncertainties, and interpreting preferences. Therefore, it is valuable to compare their outcomes.

Based on the bibliometric analysis, multicriteria evaluation methods have garnered considerable research interest. Oblak (2014) used two methods (ABC analysis and the multicriteria decision-making method) to diagnose the environmental conditions of the workplaces in the timber industry. Kiselakova et al. (2020) used multidimensional comparative analysis to compare the total synthetic measure value of sustainable development for each European Union country using data from 2018.

Several studies have employed the TOPSIS method to assess the financial performance of specific industries, e.g., five major airlines in Taiwan (Feng and Wang 2000); logistics companies (Çakır and Perçin 2013); companies operating in the iron, steel, and metal industries (Bakırcı et al. 2014); and Taiwanese container shipping companies (Wang 2014). Jenčová (2018) evaluated sixty companies operating in the electrical engineering industry using the ranking method, scoring method, normed variable method, and TOPSIS method based on specified criteria. Jenčová et al. (2019) used the mentioned methods to determine the financial and economic position of spa companies from 2013 to 2017. The authors used four financial indicators, i.e., return on assets, return on sales, personal costs-to-net turnover ratio, and value added-to-sales ratio. Krivka (2014) evaluated how the economic crisis affected Lithuanian industries. His research covers 68 industries over the period of 2006–2011, which are assessed based on a set of 10 financial ratios (profitability, liquidity, solvency, and asset turnover). The author used several multicriteria decision-making methods, such as SAW (Simple Additive Weighting), TOPSIS, and VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje), which distinguished between pre-crisis, crisis, and post-crisis periods and identified the sectors most and least affected by the economic crisis. Uygurtürk and Korkmaz (2012) analyzed the financial performance of 13 major metal industry companies in Istanbul from 2006 to 2010 using the TOPSIS method. A study by Ucuncu et al. (2018) aimed to evaluate the financial performance of seven companies in the paper industry traded on BIST (Borsa Istanbul) in 2016 using the TOPSIS method.

The TOPSIS method has been used in several studies to select a suitable supplier or supply chain. These studies focused on different industries, e.g., the engineering industry (Du and Yu 2008), gas and oil industry (Wang et al. 2018), steel industry (Azimifard et al.

2018), chemical industry (Tong et al. 2019), food processing industry (Ortiz-Barrios et al. 2020a), automotive industry (Narayana et al. 2020), mining industry (Ortiz-Barrios et al. 2021), textile industry (Kumar et al. 2022), and pharmaceutical industry (Qorri et al. 2022). Acar et al. (2015) used the TOPSIS method to assess the sustainability performance of companies, focusing on a corporate group in the textile industry.

The TOPSIS method has been utilized in numerous other studies as well. Wang and Wang (2014) used the method to assess the competitiveness of the Chinese high-tech industry in 2011. A study by Ilban and Yildirim (2017) analyzes the tourism performance of the world's 15 most popular tourist destinations over six years from 2009 to 2014. Do et al. (2020) identified the critical parameters of the Vietnamese coffee industry. A study by Weerathunga et al. (2020) evaluated the sustainability performance of the Sri Lankan hotel industry using data from 25 hotels listed on the Colombo Stock Exchange (CSE). The TOPSIS method has been used in the evaluation of hospitals in the research by Shafii et al. (2016), Jafari et al. (2020), and Ortiz-Barrios et al. (2020b).

In other research, different methods besides TOPSIS have been employed. Celek et al. (2021) used the MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) and TOPSIS methods to select suitable industrial robots in the aerospace industry. Kecek and Demirağ (2016) used TOPSIS and MOORA in the IT sector. Mansory et al. (2014) used the TOPSIS and DEA (Data Envelopment Analysis) methods to evaluate 28 active companies in the cement industry accepted in the Tehran stock market during 2006–2011. Duman et al. (2017) combined the DEA and TOPSIS methods to evaluate the retail performance of the food industry. Rouyendegh et al. (2020) assessed the performance of the retail industry in Turkey using integrated intuitionistic fuzzy TOPSIS and DEA. Le and Lu (2022) explored the competitiveness of the pharmaceutical multinational enterprises listed in the Forbes Global 2000 using DEA, rough set theory, and the TOPSIS method. Mardani et al. (2022) used TOPSIS, VIKOR, SAW, and AHP (Analytic Hierarchy Process) to rank six public hospitals in Iran.

In particular, after applying multicriteria methods, using scaling models of multivariate statistical analysis, such as MDS, can be especially effective. Using MDS, Sagarra et al. (2017) highlighted the important aspects of the data when exploring the efficiency of Mexican universities. The MDS method has also been applied in the analysis of various industries. Czillingová et al. (2012) discussed the implementation of multivariate statistical methods used to compare the financial health of selected global steel producers. They analyzed the development of the steel industry between 2003 and 2007 using factor analysis, MDS, and cluster analysis. Štefko et al. (2020) used MDS to determine the position of 21 Slovak spa companies, as well as the Slovak spa industry, within NACE 86—Human Health Activities and NACE 86.9—Other Human Activities. Jenčová et al. (2022) used MDS to compare the financial position of the 60 largest companies operating in the Slovak food processing industry in the NUTS II regions of Slovakia (Western, Central, and Eastern). In addition, the authors compared these companies in space using multicriteria evaluation methods. Wu et al. (2011) highlighted the use of MDS in the continuous development of an evaluation model, leveraging Balanced Scorecard criteria to aid hospitals in selecting the most appropriate strategies. Prejmorean and Vasilache (2009) utilized MDS as a key tool to reveal differences in patients' perceptions of healthcare service quality, drawing on data from a sample of ten Romanian clinics.

From the literature review conducted, there are very few studies that use multicriteria evaluation methods or MDS in evaluating hospitals. We are not aware of any study that combines both methods in this field. Therefore, we have identified a research gap in the application of the previously mentioned multicriteria methods and MDS for Slovak hospital evaluation.

When ranking Slovak hospitals using four different multidimensional methods across three distinct periods, several hypotheses could be formulated to explore various aspects of the analysis.

First, we will examine the correlation between rankings produced by different multidimensional methods, assessing how effectively each method represents hospital performance relative to others. This means we will test whether these different multidimensional methods, despite their varying approaches, produce similar rankings for the hospitals or not. It assesses the robustness of the rankings across different evaluation techniques. The hypotheses are as follows:

**Hypothesis 1a.** *The rankings of the Slovak hospitals will show significant consistency across the four different multidimensional methods.*

**Hypothesis 1b.** *The rankings derived from the four multidimensional methods will show varying degrees of correlation, reflecting differences in how effectively each method captures hospital performance.*

Second, we will explore whether the performance rankings of hospitals change over time, which could be due to the COVID-19 pandemic. The hypothesis is as follows:

**Hypothesis 2.** *The rankings of the Slovak hospitals will vary significantly across the three different periods, indicating the influence of the COVID-19 pandemic on hospital performance.*

Third, in the context of analyzing Slovak hospitals over three periods, MDS can help visualize the similarities and differences among these hospitals in a simplified two-dimensional space. By doing so, we aim to maintain the essential information and relationships from the original high-dimensional data. Specifically, we expect that hospitals with similar characteristics will be closer to each other in the two-dimensional space, forming distinct clusters that correspond to their categories or performance metrics. If the MDS model shows a low stress value, it indicates that the two-dimensional representation accurately reflects the distances between hospitals in the original high-dimensional space, preserving the overall structure of the data. The hypothesis is as follows:

**Hypothesis 3.** *The data from the analyzed Slovak hospitals across three periods can be effectively represented in a two-dimensional space without a significant loss of information, as measured by the stress value.*

### 3. Materials and Methods

#### 3.1. Data

The research sample consists of health facilities within the Ministry of Health of the Slovak Republic transformed into public limited companies and hospitals within the Ministry of Health of the Slovak Republic, the Ministry of Defence of the Slovak Republic, and the Ministry of Interior of the Slovak Republic, according to NACE 86—Human Health Activities, and NACE 86.1—Hospital activities (see Table 3). These are all eleven Slovak hospitals classified under NACE 86.1 (according to the Statistical Classification of Economic Activities in the European Community). The map in Figure A1 (in Appendix A) displays the positions of the analyzed hospitals.

This paper aims to apply multicriteria methods to assess hospitals in Slovakia in the pre-crisis (2019), crisis (2021), and post-crisis (2023) periods of the COVID-19 pandemic. The year 2019 represents the healthcare system's baseline performance before the COVID-19 pandemic, allowing for a comparison with later years affected by the crisis. In Slovakia, 2021 was the year of the global pandemic COVID-19. During the subsequent crisis, the Slovak health sector was financially depleted, understaffed in terms of capacity and human resources, weak in terms of capital, dysfunctional in terms of data, and technologically underdeveloped. This year captured the peak challenges faced by the healthcare system. Assessing hospitals in 2023 helps understand its lasting impacts and the effectiveness of recovery strategies. By this year, the healthcare system may have started to recover or adapt to the pandemic's long-term effects.



**Table 3.** List of analyzed hospitals.

Hospital	Code
University Hospital Bratislava	BA
Louis Pasteur University Hospital in Košice	KE
F.D. Roosevelt University Hospital with Policlinic Banská Bystrica	BB
University Hospital Martin	MT
Faculty Hospital of J. A. Reiman, Prešov	PO
Central Military Hospital—Teaching Hospital Ružomberok	RK
Faculty Hospital Trenčín	TN
Faculty Hospital Nitra	NT
Faculty Hospital and Policlinic of Žilina	ZA
Faculty Hospital Trnava	TT
Faculty Hospital and Policlinic, Nové Zámky	NZ

Seven indicators were entered into the analysis. Their list and the source from which they were obtained are presented in Table 4. The criteria were designed and determined based on absolute data, which significantly determined hospital funding.

**Table 4.** List of variables and source.

Variable	Source
Patient Satisfaction	Ministry of Health of the Slovak Republic, Institute for Economic and Social Reforms
Quality	Ministry of Health of the Slovak Republic
Personal Costs-to-Sales Ratio	Register of Financial Statements of the Slovak Republic, Financial statements of hospitals
Return on Assets (ROA)	Register of Financial Statements of the Slovak Republic
Return on Sales (ROS)	Financial statements of hospitals
No. of Employees/No. of Beds	Register of Financial Statements of the Slovak Republic
Equity-to-Total Debt Ratio	Register of Financial Statements of the Slovak Republic

The Patient satisfaction and Quality variables were obtained from the rating of hospitals evaluated by the Institute for Economic and Social Reforms. Indicators can take values from 0 to 100 points. Patient satisfaction comprises overall patient satisfaction and patient complaints. Overall patient satisfaction represents the average of 12 statutory quality indicators on inpatients' perceptions of healthcare provision (assessment of satisfaction with the care, behavior and information provided by medical staff, assessment of the quality of accommodation, ward cleanliness and food, assessment of satisfaction with the healthcare provided, and subjective perceptions of the success of treatment). Patient complaints represent the total number of complaints against a hospital in relation to 1000 inpatients that were addressed to the Health Care Surveillance Authority (HCSA) and where the HCSA terminated the supervision of the provider in question. The sub-indicators that make up the Quality indicator relate to selected statutory quality indicators in healthcare outcomes. The sub-indicators and their definition are determined by the Ministry of Health of the Slovak Republic. Health insurance companies are obliged to monitor these indicators. They draw data from the healthcare provided, which are reported to them by individual providers.

Input values forming the indicator No. of Employees/No. of Beds were derived from the Register of Financial Statements of the Slovak Republic. This indicator is a measure that helps evaluate the staffing efficiency and resource allocation within a hospital. This ratio indicates how many employees are available per bed in the hospital.

Efficiency and intensity ratios were used to represent financial ratios, with a preference for indicators from the Du Pont equation in the analysis. Efficiency was quantified by ROA and ROS. ROA is a financial performance metric that measures how effectively a hospital uses its assets to generate profit. ROS is a financial metric that measures a hospital's operational efficiency and profitability relative to its sales revenue. The intensity was

quantified by the Personal Costs-to-Sales Ratio variable. Debt ratios were represented by the Equity-to-Total Debt Ratio variable, a crucial financial metric for assessing whether a company is in or at risk of a crisis.

Statistical analysis was performed using Stata software, Statistica software, and MS Excel.

### 3.2. Multicriteria Methods

In the statistical analysis of multivariate data in the context of financial management, this paper will apply the ranking method, scoring method, normed variable method, and TOPSIS method. Multicriteria evaluation methods respond differently to interactions between indicators, so they may rank objects (hospitals) differently. Given this fact, it is also interesting to compare the resulting ranking of objects by each method.

Considering the ranking method, the hospital with the lowest rank sum (average) value can be identified as the highest-ranked hospital. The integral indicator  $d_{1i}$  for the  $i$ -th hospital is given (in the case of unit weights) by

$$d_{1i} = \frac{1}{m} \sum_{j=1}^m s_{ij}. \quad (1)$$

This method is a straightforward approach to ordering alternatives based on certain criteria. Each hospital is ranked according to its performance on individual criteria. These rankings are then aggregated across all criteria to produce an overall rank. This method is simple to understand and implement. It allows for easy comparison between hospitals by providing a clear ordinal ranking.

In the scoring method, for each decision unit indexed by  $i$ , the optimal value is sought based on the individual indicator  $x_{ij}$ , which is specific to each object. The integral indicator  $d_{2i}$  for the  $i$ -th hospital is given by

$$d_{2i} = \frac{1}{m} \sum_{j=1}^m b_{ij}. \quad (2)$$

This method provides a more nuanced evaluation than simple ranking by considering both the performance level and the relative importance of each criterion. It can distinguish between hospitals that are close in rank but different in performance.

In the normed variable method, the original values of the individual selected variables are transformed into a normalized (standardized) form. The integral indicator  $d_{3i}$  for the  $i$ -th hospital is calculated according to

$$d_{3i} = \frac{1}{m} \sum_{j=1}^m u_{ij}. \quad (3)$$

Standardization helps to eliminate the effects of different scales of measurement, allowing for a fair comparison across criteria. It also highlights how hospitals perform relative to the average.

The TOPSIS method is widely acknowledged as one of the most accurate multicriteria evaluation methods. The method works on the principle that the optimal alternative should have the smallest geometric distance from a positive-ideal solution (Thakkar 2021). All parameters are first normalized, and then the Euclidean distances from each object to the ideal object are calculated. The hospital closest to the ideal solution is ranked the highest. The integral indicator  $d_{4i}$  for the  $i$ -th hospital is given by

$$d_{4i} = \frac{1}{m} \sqrt{\sum_{j=1}^m (u_{ij} - u_{0j})^2} \quad (4)$$

In the above Equations (1)–(4),  $m$  is the number of indicators,  $s_{ij}$  denotes the order for the  $i$ -th object for the  $j$ -th indicator,  $b_{ij}$  denotes the number of points for the  $i$ -th object for the  $j$ -th indicator,  $u_{ij}$  is the standardized (normed) value of the  $j$ -th indicator of the  $i$ -th object, and  $u_{0j}$  is the standardized (normed) value of the  $j$ -th indicator of the ideal object.

Subsequently, the objective is to determine whether the four multicriteria evaluation methods provide consistent rankings of hospitals. The consistency of the hospital ranking results generated by the mentioned multicriteria methods is verified through Spearman's rank correlation coefficient. In addition, we use the Kendall concordance coefficient that measures the degree of agreement among rankings. The Kendall concordance coefficient varies from 0 to 1. Values close to zero represent a lack of agreement in the rankings of the hospitals among multicriteria methods, while values close to 1 represent perfect agreement in the rankings of the hospitals among methods. The Kendall concordance coefficient will also be employed to evaluate if hospital rankings have changed over time.

### 3.3. Multidimensional Scaling

MDS is a multivariate data analysis technique that aims to represent high-dimensional data in a lower-dimensional space. The input data for MDS analysis is based on the measured dissimilarities or similarities among the observed objects. When the MDS technique is applied to the measured dissimilarities or similarities, it produces a spatial map. In the spatial map, objects that are dissimilar are positioned far apart, while similar objects are placed close to each other (Saeed et al. 2018). MDS represents proximity data as distances among points in a multidimensional space. MDS encompasses a variety of models that differ in how they convert proximities into distances and in the distance functions they use. Typically, Euclidean distances are chosen as the targets in MDS. Generally, we differentiate between classical multidimensional scaling (Principal Coordinate Analysis) and nonmetric multidimensional scaling (NMDS). Principal Coordinate Analysis has the drawback that its primary coordinates are not straightforwardly interpretable using the original variables. One benefit is that NMDS can effectively handle more missing values in the association matrix if sufficient information remains to position each object relative to the others. Additionally, NMDS is robust against outliers, which is another advantage (Vasanicova et al. 2022). NMDS can handle various types of data, including ordinal, categorical, and continuous data. NMDS can be applied to both small and large datasets, making it a versatile tool for exploratory data analysis. NMDS does not assume linear relationships between variables. The graphical representation produced by NMDS often provides an intuitive and accessible way to understand relationships within the data, even for those without a deep statistical background. NMDS is chosen to analyze hospital performance because it accommodates the complexity, diversity, and nonlinearity of hospital data, providing robust, interpretable visualizations that help stakeholders make informed decisions.

The formal goodness of an MDS solution is measured by calculating its stress value. The stress value serves as a diagnostic tool to assess whether the dimensionality reduction is effective or if additional dimensions might be needed for a better representation of the data. It allows for the comparison of different NMDS solutions with varying dimensions or starting configurations to determine which provides the best representation of the data. Stress, a loss function, equals zero for a perfect solution and is greater than zero otherwise (Borg et al. 2018). Stress minimizes the fit discrepancy between the model-derived distances and the observed distances (Ding 2018). Kruskal (1964) suggested the following rule of thumb for the stress value: 0.00—perfect; 0.025—excellent; 0.05—good; 0.10—fair; 0.20—poor. Lower stress values indicate a better fit, meaning that the distances in the NMDS plot more accurately reflect the dissimilarities in the original data.

Within this research, our hypothesis is that our data can be effectively represented in a two-dimensional space without a significant loss of information. In addition, the distances between hospitals in the original high-dimensional space will be preserved in the two-dimensional space. It means that hospitals belonging to the same category will cluster

together in the two-dimensional space. Lower stress values indicate a better fit, meaning the low-dimensional representation accurately reflects the original distances.

#### 4. Results

The criteria set is appropriate because no pair of indicators has shown evidence of multicollinearity. Table 5 presents the ranking of hospitals in the pre-crisis (2019), crisis (2021), and post-crisis (2023) periods of the COVID-19 pandemic, following the application of multicriteria evaluation methods.

**Table 5.** Ranking of hospitals. Source: own processing.

Hospital	Rank in 2019				Rank in 2021				Rank in 2023			
	A	B	C	D	A	B	C	D	A	B	C	D
BA	7	2	4	4	9	11	10	10	3	9	5	5
KE	10	7	8	8	11	9	11	11	11	11	11	11
BB	3	3	2	2	4	6	1	1	1	2	2	1
MT	8	5	5	6	10	10	9	9	8	5	3	3
PO	9	10	10	10	8	7	8	8	6	8	7	6
RK	1	1	1	1	6	8	3	3	2	1	1	2
TN	4	11	9	9	1	3	5	5	4	10	10	10
NT	2	4	3	3	2	2	2	2	9	3	6	8
ZA	11	9	11	11	7	5	6	6	5	4	4	4
TT	6	6	6	5	5	4	7	7	10	6	8	7
NZ	5	8	7	7	3	1	4	4	7	7	9	9

Note: A, B, C, and D denote methods in this order: ranking method, scoring method, normed variable method, and TOPSIS.

As we have mentioned, the TOPSIS method is one of the most accurate approaches for multicriteria evaluation. Therefore, the hospital rankings presented in Table 5 are described based on this method. In 2019, RK secured the top position. BB was second, followed by NT. The last place was taken by ZA. Hospitals among the top three in 2019 maintained their positions in the top three in 2021. However, the ranking was as follows: BB (first), NT (second), BB (third). The last place belonged to KE in 2021, and also in 2023. NT did not achieve a top-three ranking in 2023. First place was again taken by BB and second place was taken by RK. Third place went to MT.

Spearman's rank correlation coefficients, in Table 6, verify the consistency of the hospital ranking results generated by multicriteria methods. The highest concordance of hospital rankings is between the normed variable method and TOPSIS. On the other hand, there is statistically insignificant agreement between the ranking and scoring methods (except in 2021). The Kendall concordance coefficient measures the degree of agreement among rankings. The lowest Kendall coefficient of concordance observed in 2023 is attributed to the poor agreement between the ranking method and the scoring method. Nevertheless, the agreement between the multicriteria evaluation methods employed was statistically significant. We confirm Hypothesis 1a that the rankings of the Slovak hospitals would show significant consistency across the four different multidimensional methods and reject Hypothesis 1b that the rankings derived from the four multidimensional methods would show varying degrees of correlation, reflecting differences in how effectively each method captures hospital performance.

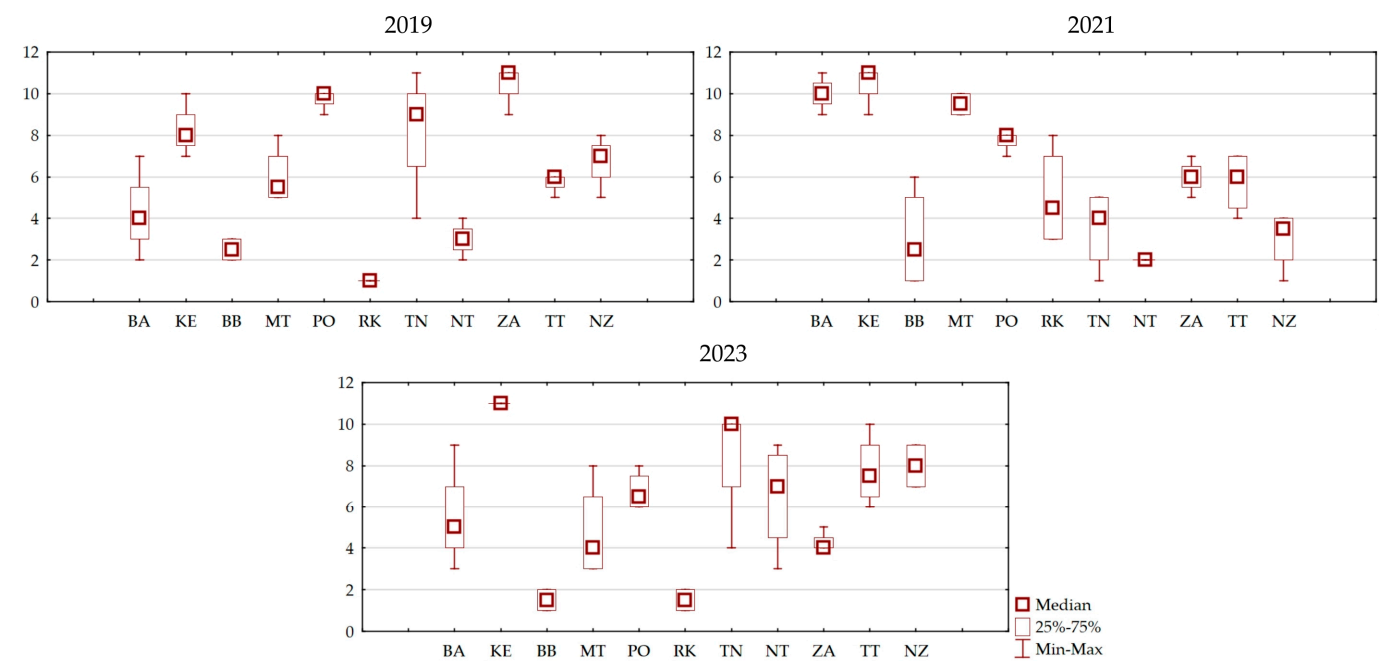
The boxplots in Figure 4 visualize the differences in hospital rankings across the various methods. These factorized boxplots are crucial for understanding the impact of methodological differences on hospital rankings. In these boxplots, the square within each box indicates the median ranking for the hospital across the used methods. The interquartile range (IQR), indicated by the height of the box, represents the range where the central 50% of the rankings lie, illustrating the degree of consistency or variability in hospital performance. The 'whiskers' extending from the boxes represent the range of rankings. The lowest variability was observed for RK and BB (in 2019), NT and MT (in

2021), KE, BB, and RK (in 2023). On the other hand, the highest variability was found for TN and BA (in 2019); BB, RK, and TN (in 2021); and TN, NT, and BA (in 2023).

**Table 6.** Consistency of the hospital ranking among methods. Source: own processing in Statistica.

Panel A: Spearman's Rank Correlation Coefficient												
Method	2019				2021				2023			
	A	B	C	D	A	B	C	D	A	B	C	D
A		0.500	0.755	0.773		0.864	0.809	0.809		0.364	0.609	0.636
B	0.500		0.927	0.918	0.864		0.636	0.636	0.364		0.827	0.745
C	0.755	0.927		0.991	0.809	0.636		1.000	0.609	0.827		0.964
D	0.773	0.918	0.991		0.809	0.636	1.000		0.636	0.745	0.964	
Panel B: Kendall Coefficient of Concordance												
0.858				0.844				0.768				

Note: A, B, C, and D denote methods in this order: ranking method, scoring method, normed variable method, and TOPSIS. Bold text indicates statistical significance at the 0.05 level.

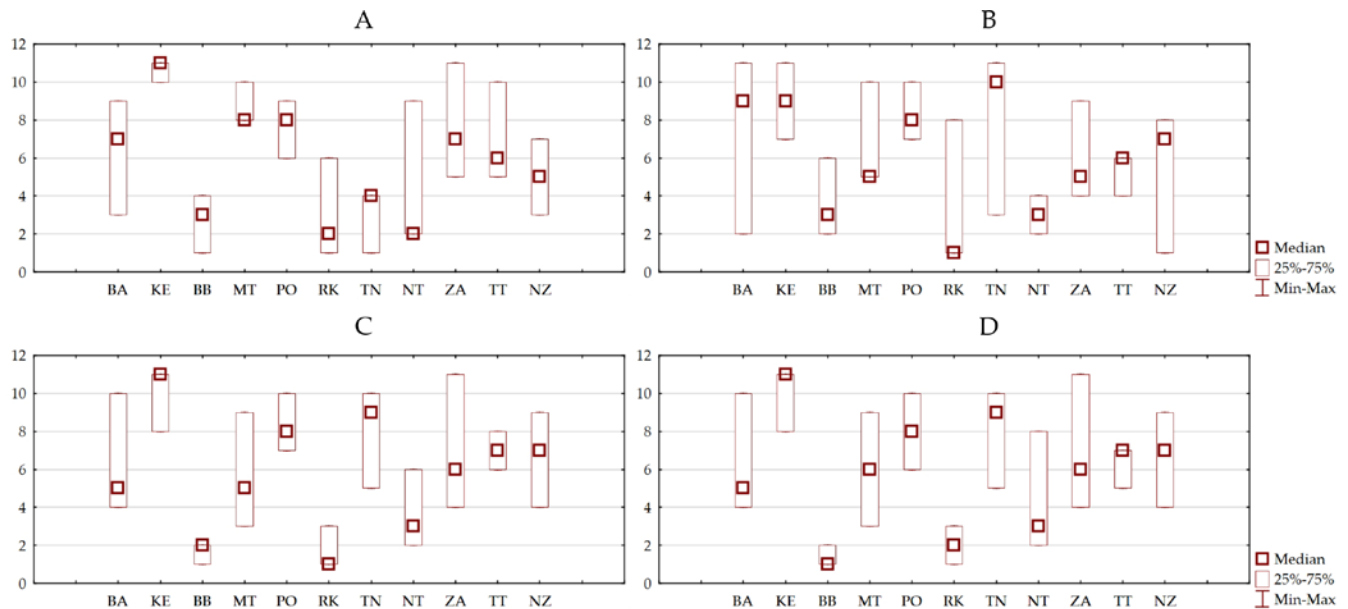


**Figure 4.** Factorized boxplots of the hospital rankings in the analyzed years. Source: own processing in Statistica.

The findings in Table 5 indicate that hospital rankings based on the chosen criteria vary over time. This variation underscores the dynamic nature of hospital performance and highlights how external factors, such as changes in healthcare policies and resource availability, as well as the impact of events like the COVID-19 pandemic, can influence hospital performance metrics. For instance, during the pandemic (2021), hospitals faced unprecedented challenges that could have affected their operational efficiency and patient outcomes, leading to shifts in their rankings. The boxplots in Figure 5 visualize the differences in hospital rankings across the analyzed periods (2019, 2021, 2023). Factorized boxplots provide a clear visual representation of the distribution and variation in hospital rankings across the analyzed years. In these boxplots, the square within each box indicates the median ranking for the hospital across the analyzed periods. The interquartile range (IQR), depicted by the height of the box, shows the range within which the middle 50% of the rankings fall, highlighting the consistency or variability of hospital performance. Alongside the TOPSIS method, we also present boxplots for the other three multicriteria



methods used. The lowest variability was observed for KE (using the ranking method, denoted as A), NT (using the scoring method, denoted as B), and BB (using the normed variable method, denoted as C, and TOPSIS, denoted as D). On the other hand, the highest variability was found for NT (using the ranking method, denoted as A); BA, RK, and TN (using the scoring method, denoted as B); and ZA (using the normed variable method, denoted as C, and TOPSIS, denoted as D).



**Figure 5.** Factorized boxplots of the hospital rankings according to various multicriteria methods. Source: own processing in Statistica. Note: (A–D) denote methods in this order: ranking method, scoring method, normed variable method, and TOPSIS.

Also, the Kendall concordance coefficients in Table 7 show a low degree of agreement among the rankings in time. We confirm Hypothesis 2 that the rankings of the Slovak hospitals would vary significantly across the three different periods, indicating the influence of the COVID-19 pandemic on hospital performance. The observed fluctuations in hospital rankings over the analyzed period reflect broader changes in the healthcare landscape and emphasize the need for continuous monitoring and adaptive strategies to ensure high-quality patient care and efficient hospital management.

**Table 7.** Consistency of the hospital rankings over time. Source: own processing in Statistica.

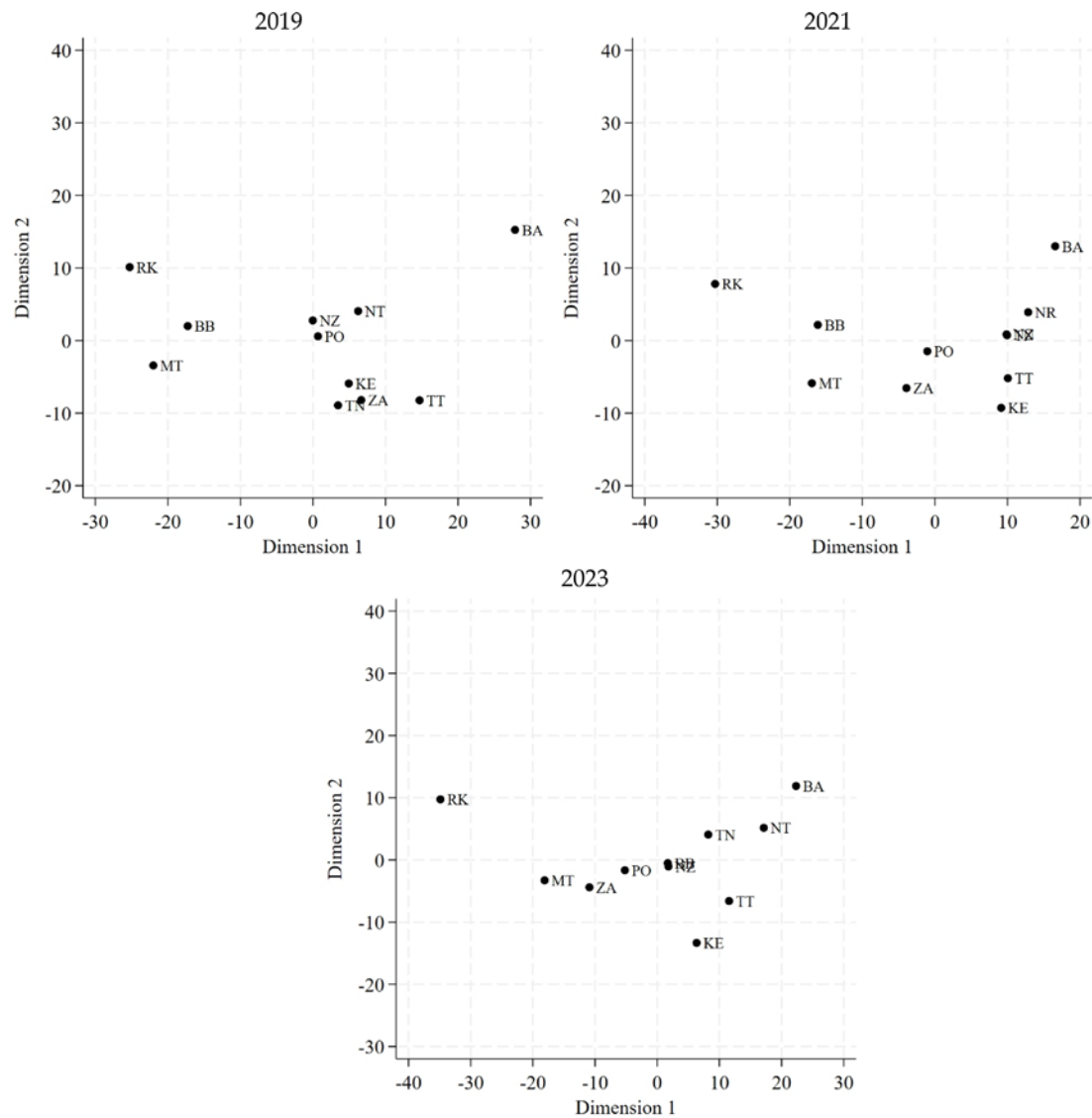
	Method			
	A	B	C	D
Kendall coefficient of concordance	0.622	0.392	0.646	0.602

Note: A, B, C, and D denote methods in this order: ranking method, scoring method, normed variable method, and TOPSIS.

Figure 6 depicts two-dimensional plots generated using the NMDS method, with each plot illustrating the outcome for a specific year.

The NMDS enables the visualization of the similarity levels between hospitals by depicting their proximity in the generated plot. For these plots, we provide the stress function values in Table 8. The quality of all three models is perfect, as the stress function values are below 0.025. These low stress values indicate that the two-dimensional plots created by NMDS accurately capture the similarities or dissimilarities between hospitals. These low stress values suggest that the dimensional reduction did not significantly distort

the data. We confirm Hypothesis 3 that the data from the analyzed Slovak hospitals across the three periods could be effectively represented in a two-dimensional space without a significant loss of information, as measured by the stress value. Given the high quality of the models, the visual comparisons between hospitals based on the NMDS plots are trustworthy. Differences or clusters observed in the NMDS plots can be interpreted as true reflections of the relationships between the hospitals in the data.



**Figure 6.** Nonmetric multidimensional scaling–matching configuration plots. Source: own processing in Stata.

**Table 8.** Stress function. Source: own processing in Stata.

NMDS for Year	2019	2021	2023
Stress	0.0022	0.0017	0.0042

Tables 9–11 present the distances between the hospitals in 2019, 2021, and 2023. They are calculated based on matrix similarity (dissimilarity) measures using Euclidean distances in Stata software. The greater the distance between objects, the more distinct the object is from its competitors.

Before the COVID-19 pandemic (2019), NZ and PO (2.35), ZA and KE (2.88), and ZA and TN (3.40) were the most similar hospital pairs in Slovakia. In contrast, BA and RK (53.38), BA and MT (53.24), and BA and BB (47.01) were the most dissimilar. During the COVID-19 pandemic (2021), NZ and TN (0.32), TT and KE (4.23), and NZ and ZA (4.32) were the most similar pairs of Slovak hospitals. On the contrary, BA and RK (47.18), NT and PO (43.31), and RK and KE (42.96) were the most different hospital pairs. After the COVID-19 pandemic (2023), NZ and BB (1.10), ZA and PO (6.34), and NZ and PO (7.02) were the most similar hospital pairs in Slovakia. On the other hand, BA and RK (57.23), NT and RK (52.19), and TT and RK (49.21) were the most different pairs.

**Table 9.** Distances between hospitals in 2019. Source: own processing in Stata.

Hospital	BA	KE	BB	MT	PO	RK	TN	NT	ZA	TT	NZ
BA	0.00										
KE	31.25	0.00									
BB	47.01	23.54	0.00								
MT	53.24	27.02	7.22	0.00							
PO	30.82	7.84	18.04	23.09	0.00						
RK	53.38	34.19	11.42	13.94	27.68	0.00					
TN	34.24	3.58	23.46	26.12	9.91	34.49	0.00				
NT	24.48	10.15	23.59	29.19	6.64	32.08	13.18	0.00			
ZA	31.63	2.88	25.97	29.02	10.63	36.78	3.40	12.28	0.00		
TT	26.94	10.08	33.54	37.00	16.57	43.97	11.24	14.91	8.09	0.00	
NZ	30.55	10.05	17.28	22.86	2.35	26.32	12.12	6.42	12.83	18.36	0.00

Note: The color scale from green to red represents the range from the lowest to the highest distances.

**Table 10.** Distances between hospitals in 2021. Source: own processing in Stata.

Hospital	BA	KE	BB	MT	PO	RK	TN	NT	ZA	TT	NZ
BA	0.00										
KE	23.41	0.00									
BB	34.49	27.73	0.00								
MT	38.48	26.31	8.08	0.00							
PO	22.81	12.83	15.54	16.52	0.00						
RK	47.18	42.96	15.25	19.11	30.71	0.00					
TN	13.91	10.12	26.09	27.69	11.19	40.82	0.00				
NT	9.94	13.68	29.04	31.35	14.92	43.31	4.37	0.00			
ZA	28.32	13.35	15.00	13.05	5.85	30.03	15.67	19.76	0.00		
TT	19.32	4.23	27.21	27.02	11.71	42.40	6.01	9.54	14.05	0.00	
NZ	13.91	10.11	26.09	27.69	11.19	40.82	0.32	4.32	15.67	6.00	0.00

Note: The color scale from green to red represents the range from the lowest to the highest distances.

**Table 11.** Distances between hospitals in 2023. Source: own processing in Stata.

Hospital	BA	KE	BB	MT	PO	RK	TN	NT	ZA	TT	NZ
BA	0.00										
KE	29.84	0.00									
BB	24.18	13.36	0.00								
MT	43.18	26.42	20.01	0.00							
PO	30.68	16.42	7.05	13.03	0.00						
RK	57.23	47.21	38.09	21.22	31.80	0.00					
TN	16.17	17.50	8.16	27.33	14.57	43.45	0.00				
NT	8.52	21.42	16.52	36.23	23.36	52.19	9.03	0.00			
ZA	37.00	19.42	13.16	7.30	6.34	27.82	20.90	29.62	0.00		
TT	21.40	8.53	11.43	29.85	17.47	49.21	11.19	13.05	22.57	0.00	
NZ	24.18	13.38	1.10	20.04	7.02	38.11	8.07	16.50	13.18	11.41	0.00

Note: The color scale from green to red represents the range from the lowest to the highest distances.

Based on the findings in Tables 9–11 and Figure 6, we can derive that hospitals BA and RK occupy a distinct position (on average, the highest distance values in Tables 9–11 and the most distant position in Figure 6). In 2019 and 2021, we could also include MT and BB.

The most different from all the other hospitals is RK, which falls under the Ministry of Defence of the Slovak Republic, not under the Ministry of Health of the Slovak Republic. It distinguishes itself from other hospitals by several advantages. Its Versius robotic system is the only one in Slovakia that assists in surgeries in the hospital; it has an emergency reception of type II; it has the most modern laboratory in Slovakia; and it has a new modern CT angiography workstation. It represents the largest military medical facility on the territory of the Slovak Republic at the ROLE 4 level (according to NATO standards).

In terms of excellence, BB is the only hospital in the Slovak Republic with two da Vinci Robotic Surgical Systems.

## 5. Discussion

The current body of literature comprises multiple studies on analogous topics. Nevertheless, there is an absence of studies that integrate the same methodologies (multicriteria methods and NMDS), criteria (seven indicators), periods (2019, 2021, 2023), and geographical focus (Slovakia) as our research.

Sendek et al. (2015) applied DEA to evaluate the efficiency of Czech and Slovak hospitals in 2009–2012. The number of beds, working hours and overtime hours of physicians and nurses, and bed days, as well as the cost of medicine and medical products, represented their input measures. On the other hand, the number of hospitalizations and outpatient visits in hospitals were their output variables. Sendek (2014) conducted the same study on a sample of Slovak hospitals. Stefko et al. (2018) chose a similar approach to evaluate the efficiency of eight Slovak hospitals in 2008–2015. The number of beds, number of medical staff, number of CTs, number of MRs, and number of medical equipment together were their input variables. The bed occupancy rate and average nursing time in days represented their output measures. The research by Gavurova and Kocisova (2020) similarly focused on assessing the efficiency of Slovak hospitals. DEA was provided between 2015 and 2018. The authors selected three input variables (number of doctors/nurses/beds per hospitalized patient), four intermediates (average length of hospital stay, surgical procedure rate, surgical planning, and median waiting time for emergency admission), and four outputs (healthcare, staff access to patients, patient information, and hotel services). Zaim et al. (2008) assessed the effectiveness of twelve hospitals in Turkey using DEA. Inputs to the model included the number of beds, the number of physicians, and key aspects of total quality management in healthcare. Outputs considered in the analysis encompassed both financial and non-financial hospital performance metrics, including the number of outpatients and patient days. Soares et al. (2017) investigated and compared the efficiency of 21 public hospitals in Brazil using DEA. The authors used four inputs (number of medical and non-medical staff, annual revenue, number of beds, and average length of patient hospitalization), four variables of influence (type of hospital, accredited hospital, number of medical specialties, and resources from government), and four outputs (number of outpatient care services, number of hospitalizations, number of surgeries, and number of exams).

Wu et al. (2011) detailed the continuous development of an evaluation model using Balanced Scorecard criteria to assist hospitals in selecting an appropriate strategy using MDS. Their findings indicated that the three subject hospitals maintained a balance across customer perspectives, learning and growth, internal business processes, and financial measures. Prejmorean and Vasilache (2009) used MDS to present the differences in patient perceptions of healthcare service quality based on a sample of ten Romanian clinics. The authors evaluated the competencies of the doctors, the competencies of the nurses, and the empathy of the staff. Their results identified the factors that lead patients to perceive groups of clinics similarly.

Ortiz-Barrios et al. (2020b) introduced a hybrid fuzzy decision-making model to assess Turkish hospitals' disaster preparedness. The authors used the TOPSIS method to obtain a

ranking of hospitals. Their model integrates six criteria for disaster preparedness (hospital buildings, equipment, communication, transportation, personnel, and flexibility), along with thirty-six sub-criteria that cover all aspects of hospital disaster management. A study by [Shafii et al. \(2016\)](#) aimed to assess the service quality of three teaching hospitals at Yazd University of Medical Sciences (Iran) using six dimensions (responsiveness, assurance, security, tangibles, health communication, and patient orientation). The TOPSIS method was used to rank hospital wards. [Jafari et al. \(2020\)](#) evaluated the performance of eleven Iranian hospitals using AHP and TOPSIS. The hierarchical analysis results indicated that the primary indicators used to assess hospital performance were bed turnover rate, emergency patients, and length of hospital stays. [Kadoić et al. \(2021\)](#) aimed to create a method for ranking leading hospitals at the national level in Croatia. They combined composite indicator methodology with the AHP and used data connected with acute myocardial infarction, cerebrovascular insult, and antimicrobial prophylaxis in colorectal surgery. A study by [Mardani et al. \(2022\)](#) ranked six public hospitals in Iran. The authors used eleven criteria in terms of waste control and compared the scores of four multicriteria methods (TOPSIS, VIKOR, SAW, and AHP).

Research by [Rocha et al. \(2021\)](#) focused on evaluating the quality of twenty-five Portuguese public hospitals. The authors discussed six dimensions (access, performance assistance, productivity, economics/finances, safety, volume, and usage) while employing the ELECTRE TRI-NC method. The method was used in a similar study by [Gregório et al. \(2024\)](#) when assessing twenty-six Portuguese hospitals.

This discussion highlights a significant absence of studies integrating multicriteria methods and NMDS, seven specific criteria, and specific time periods, particularly in the context of evaluating Slovak hospitals during the COVID-19 pandemic. Therefore, we emphasize the distinctiveness of our study compared to existing research and underscore its potential contribution to filling the identified gaps in the literature.

Multicriteria evaluation of objects in space can be used in many areas, and, therefore, in the healthcare sector, i.e., healthcare facilities (hospitals), either as a final solution or as a result that is further used in other analyses. Accurate and comprehensible data analysis using multicriteria methods often yields new insights into problems that would likely have escaped the attention of healthcare managers by simply processing them.

The Slovak healthcare sector has faced significant challenges and developments across the years 2019, 2021, and 2023, reflecting broader global trends and country-specific issues. According to [OECD \(2019\)](#), before the pandemic, the Slovak healthcare system was already under strain, largely due to chronic underfunding, staff shortages, and inefficiencies in healthcare delivery. Preventive care and public health initiatives were underemphasized.

The impact of the COVID-19 pandemic profoundly stressed Slovakia's healthcare system. The pandemic exacerbated existing issues, e.g., staff shortages, particularly of nurses and doctors, and highlighted the system's limited resilience. On the positive side, the pandemic accelerated digital health initiatives, including telemedicine, though these were still in their early stages of adoption ([OECD 2021](#)).

In 2023, the Slovak healthcare sector continued to face significant challenges, although there were some areas of improvement. The main issues persisted around workforce shortages, with a particular deficit in nursing staff, which has been a longstanding problem ([OECD 2023](#)).

A detailed mapping of the capital structure of hospitals and hospital facilities is essential to improve hospital performance. The highest objective determinant in Slovak healthcare sector performance is the funding of the healthcare system. According to [Kopčanová \(2023\)](#), in 2024, the Slovak healthcare budget was 7.97 billion euros. This is almost a billion euros more than the budget in 2023. Hospitals and the healthcare sector need to support innovation. In modern healthcare, it is essential to consistently invest in cutting-edge medical technologies. Modern instruments provide more accurate and precise measurement results, leading to better and faster diagnosis and treatment design. Innovations in Slovak healthcare include telehealth and telemedicine, electronization,



digitalization, robotization, and artificial intelligence. Unfortunately, the distribution of health technologies is highly uneven across different regions.

Health is considered a priority and a condition for a good life. This should be reason enough to ensure adequate resources for healthcare. However, the Slovak healthcare system has suffered from chronic underfunding for a long time, which is reflected in the generally poorer health of the population ([Iness and Advance Healthcare Management Institute 2023](#)). Another factor influencing the performance of the Slovak healthcare sector is the social and economic environment, particularly staff shortages. A challenge threatening the sustainability of the healthcare workforce is burnout ([Ali Taha et al. 2023](#)).

An additional problem in the Slovak healthcare sector is the inefficient management of state hospitals, especially considering their ever-increasing financial losses. In recent years, the rate of cost growth has accelerated. The main reason was to increase the salaries of health workers. Hospitals' spending on medicines, maintenance of outdated medical equipment, and energy has also risen. Simultaneously, public hospitals are unable to generate sufficient revenue from providing healthcare services to cover their expenses. These cost increases, which are not covered by revenue, lead to persistent operating losses and growing indebtedness. According to [Mogilevskaia \(2024\)](#), by the end of 2023, the amount of debt of Slovak state hospitals exceeded one billion euros. Hospital management does not exhibit minimal elements of corporate governance; debt creation is not punished but rewarded by the fact that these providers are regularly indebted to the state budget. The solution is to transform state hospitals into commercial companies with clear corporate governance rules, audited double-entry accounting, and a positive economic result.

## 6. Conclusions

The COVID-19 pandemic posed an unprecedented medical and economic challenge to the Slovak healthcare system. Efficiently utilizing available resources, mobilizing them effectively, and ensuring their proper redistribution are key factors influencing the pursuit of universal health coverage. The highest portion of healthcare spending is allocated to hospital care expenses. Therefore, effective financial management is one of the primary responsibilities of the state in the realm of healthcare.

This paper aimed to apply multicriteria methods to assess hospitals in Slovakia in the pre-crisis (2019), crisis (2021), and post-crisis (2023) periods of the COVID-19 pandemic. Three objectives followed from the aim of this paper. The first objective was to determine whether the four multicriteria evaluation methods provide consistent rankings of hospitals. The second objective was to assess whether hospital rankings shift over time (pre-crisis, crisis, and post-crisis periods of the COVID-19 pandemic). The third objective was to determine whether the distances between hospitals in the original high-dimensional space would be preserved in two-dimensional space.

In conclusion, the statistically significant agreement among the multicriteria evaluation methods employed underscores their reliability. The variability in Slovak hospital rankings over time, as revealed by our findings, highlights the dynamic nature of healthcare performance assessment (due to the COVID-19 pandemic). The high quality of the NMDS models confirms their precision in representing hospital comparisons. Integrating multicriteria methods with NMDS enhances decision-making by leveraging the complementary strengths of each approach, thereby providing deeper insights into complex datasets.

Several implications emerge from our research. Considering its theoretical implications, while the existing literature includes numerous studies on related topics, none of them utilize the exact combination of methods and criteria we have employed, and they do not focus on Slovak hospitals in the context of COVID-19. Considering its managerial implications, our study emphasizes significant criteria that hospital managers can consider when addressing (quality) improvement in healthcare facilities. The results offer management insights into identifying the hospitals with relatively superior values within the observed criteria, as well as into pinpointing comparatively inefficient hospitals when compared to those with the best values. Our results are crucial to prioritize respective actions. There-

fore, this study contributes to managerial practice by proposing specific criteria aimed at delivering effective solutions to improve hospital performance. Our findings suggest that hospital managers should use a mix of financial and non-financial indicators to accurately monitor hospital performance.

The study conducted also has several limitations. One limitation is that the evaluation was restricted to only large hospitals in Slovakia. In future research, expanding the sample to include small hospitals would be beneficial. Another limitation is that we only considered six criteria.

Future research could focus on assessing whether incorporating additional evaluation criteria enhances the accuracy of the MDS model. Moreover, further research would benefit from the addition of non-financial criteria (e.g., patient satisfaction with meals, number of patients per room, superior rooms, visiting hours, patient booking, quality of website, etc.). This would consist of information from a questionnaire that patients would complete after their inpatient stay in the hospital. Another research direction is to extend the statistical analysis of multivariate data to include factor and cluster analysis.

**Author Contributions:** Conceptualization, S.J., P.V. and M.M.; methodology, S.J. and P.V.; software, S.J. and P.V.; validation, S.J., P.V. and M.M.; formal analysis, S.J., P.V. and M.M.; investigation, S.J., P.V. and M.M.; resources, S.J.; data curation, S.J. and P.V.; writing—original draft preparation, S.J., P.V. and M.M.; writing—review and editing, S.J., P.V. and M.M.; visualization, P.V.; supervision, S.J., P.V. and M.M.; project administration, S.J., P.V. and M.M.; funding acquisition, S.J. All authors have read and agreed to the published version of the manuscript.

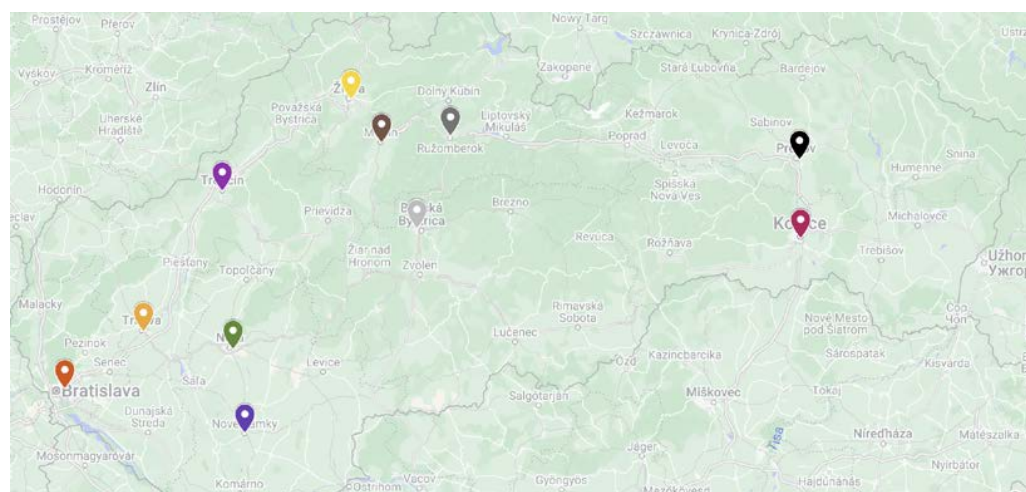
**Funding:** This research was funded by the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant No. 1/0575/23–VEGA. This research was funded by the Cultural and Educational Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic, grant No. 001PU-4/2022–KEGA.

**Institutional Review Board Statement:** Not applicable.

**Data Availability Statement:** For requests concerning the data, please contact the corresponding author.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A



**Figure A1.** Map of Slovak hospitals. Source: own processing using <http://mymaps.google.com> (accessed in 1 July 2024).

## References

- Acar, Eda, Merve Kiliç, and Mücella Güner. 2015. Measurement of Sustainability Performance in Textile Industry by Using a Multi-Criteria Decision Making Method. *Tekstil ve Konfeksiyon* 25: 3–9.

- Ali Taha, Viktória, Veronika Škerháková, and Ema Scholtz. 2023. Sustainability in Healthcare: A Conceptual Study. In *Economics, Management & Business 2023: Contemporary Issues, Insights and New Challenges, Paper presented at VIII. International Scientific Conference on Economics, Management & Business, High Tatras, Slovakia, September 28–29*. Prešov: Presov University Press.
- Ardakani, Elham Shaker, Niloofar Gilani Larimi, Maryam Oveysi Nejad, Mahsa Madani Hosseini, and Manaf Zargoush. 2023. A resilient, robust transformation of healthcare systems to cope with COVID-19 through alternative resources. *Omega* 114: 102750. [CrossRef]
- Azimifard, Arezoo, Seyed Hamed Moosavirad, and Shahram Ariafar. 2018. Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. *Resources Policy* 57: 30–44. [CrossRef]
- Bakırcı, Fehim, Seyedhadi Eslamian Shiraz, and Ali Sattary. 2014. Financial performance analysis of iron, steel metal industry companies in the Borsa İstanbul: DEA super efficiency and TOPSIS methods. *Ege Academic Review* 14: 9–19.
- Baydaş, Mahmut, Orhan Emre Elma, and Dragan Pamučar. 2022. Exploring the specific capacity of different multi criteria decision making approaches under uncertainty using data from financial markets. *Expert Systems with Applications* 197: 116755. [CrossRef]
- Borg, Ingwer, Patrick J. F. Groenen, and Patrick Mair. 2018. *Applied Multidimensional Scaling and Unfolding*. Cham: Springer.
- Ceballos, Blanca, María Teresa Lamata, and David A. Pelta. 2016. A comparative analysis of multi-criteria decision-making methods. *Progress in Artificial Intelligence* 5: 315–22. [CrossRef]
- Celek, Osman Emre, Mustafa Yurdakul, and Yusuf Tansel İç. 2021. Development of a Multi-Criteria Decision Making Model for the Selection of Appropriate Robots for the Aerospace Industry. *Journal of Polytechnic-Politeknik Dergisi* 26: 267–81. [CrossRef]
- Czillingová, Jana, Igor Petruška, and Michal Tkáč. 2012. Financial and economic analysis of steel industry by multivariate analysis. *Ekonomický časopis* 60: 388–405.
- Çakır, Süleyman, and Selçuk Perçin. 2013. Performance Measurement of Logistics Firms with Multi-Criteria Decision Making Methods. *Ege Academic Review* 13: 449–59.
- Ding, Cody S. 2018. *Fundamentals of Applied Multidimensional Scaling for Educational and Psychological Research*. New York: Springer.
- Do, Thi-Nga, Vimal Kumar, and Manh-Hoang Do. 2020. Prioritize the key parameters of Vietnamese coffee industries for sustainability. *International Journal of Productivity and Performance Management* 69: 1153–76. [CrossRef]
- Du, Zhao-hui, and Cai-hong Yu. 2008. Analysis of the manufacture supplier selection with the improved Technique for Order Preference by Similarity to Ideal Solution. Paper presented at International Conference on Management Science and Engineering, Long Beach, CA, USA, September 10–12.
- Duman, Gazi Murat, Ozden Tozanli, Elif Kongar, and Surendra M. Gupta. 2017. A holistic approach for performance evaluation using quantitative and qualitative data: A food industry case study. *Expert Systems with Applications* 81: 410–22. [CrossRef]
- Feng, Cheng-Min, and Rong-Tsu Wang. 2000. Performance evaluation for airlines including the consideration of financial ratios. *Journal of Air Transport Management* 6: 132–42. [CrossRef]
- Gavurova, Beata, and Katarina Kocisova. 2020. The efficiency of hospitals: Platform for sustainable healthcaresystem. *Entrepreneurship and Sustainability Issues* 8: 133–46. [CrossRef]
- Gregório, Beatriz Cagigal, Miguel Alves Pereira, and Ana Sara Costa. 2024. Multi-criteria decision-aiding for public hospitals: The role of interactions among pairs of access and quality criteria. *Omega* 126: 103046. [CrossRef]
- Ilban, Mehmet Oğuzhan, and Hasan Hüseyin Yildirim. 2017. Ilban. *Cogent Social Sciences* 3: 1301763. [CrossRef]
- Iness and Advance Healthcare Management Institute. 2023. *Viac peňazi do zdravotníctva je investíciou do zdravia a prosperity spoločnosti*. Available online: <https://amcham.sk/download.pl?hash=0hYYjgFfUpQi57FPgo0757uqSTdwJhk&ID=6485> (accessed on 3 September 2024).
- Jafari, Mehdi, Maryam Seyedjavadi, and Rouhollah Zaboli. 2020. Assessment of performance in teaching hospitals: Using multicriteria decision-making techniques. *Journal of Education and Health Promotion* 9: 214. [CrossRef]
- Jakušová, Viera. 2016. *Manažment pre nelekárské študijné programy*. Martin: Osveta.
- Jenčová, Sylvia. 2018. *Aplikácia pokročilých metód vo finančno-ekonomickej analýze elektrotechnického odvetvia Slovenskej republiky*. Ostrava: VSB-TU Ostrava.
- Jenčová, Sylvia, Petra Vašaničová, and Igor Petruška. 2019. Financial Position of the Slovak Spa Companies. European Financial Systems. Paper presented at 16th International Scientific Conference European Financial Systems 2019, Brno, Czech Republic, June 24–25.
- Jenčová, Sylvia, Petra Vašaničová, Beáta Gavurová, and Radovan Bačík. 2022. Financial position of companies operating in food processing industry of Slovakia by using multidimensional scaling. *Economics and Sociology* 15: 253–73. [CrossRef]
- Kadoić, Nikola, Diana Šimić, Jasna Mesarić, and Nina Begičević Ređep. 2021. Measuring quality of public hospitals in Croatia using a multi-criteria approach. *International Journal of Environmental Research and Public Health* 18: 9984. [CrossRef]
- Kecek, Gülnur, and Fatma Demirağ. 2016. A comparative analysis of TOPSIS and MOORA in laptop selection. *Research on Humanities and Social Sciences* 6: 1–9.
- Kiselakova, Dana, Stec Malgorzata, Mariola Grzebyk, and Beata Sofrankova. 2020. A Multidimensional Evaluation of the Sustainable Development of European Union Countries—An Empirical Study. *Journal of Competitiveness* 12: 56–73. [CrossRef]
- Kopčanová, Anna. 2023. Štát chce dať na zdravotníctvo takmer o miliardu eur viac než vlni. Zisťovali sme, kde na to vezme. *STARTITUP*. Available online: <https://www.startitup.sk/stat-chce-dat-na-zdravotnictvo-takmer-o-miliardu-eur-viac-nez-vlni-zistovali-sme-kde-na-to-vezme/> (accessed on 3 September 2024).

- Krivka, Algirdas. 2014. Complex evaluation of the economic crisis impact on Lithuanian industries. *Journal of Business Economics and Management* 15: 299–315. [\[CrossRef\]](#)
- Kruskal, Joseph Bernard. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* 29: 1–27. [\[CrossRef\]](#)
- Kumar, Vimal, Pratima Verma, Ajay Jha, Kuei-Kuei Lai, and Manh-Hoang Do. 2022. Dynamics of a medium value consumer apparel supply chain key parameters. *International Journal of Productivity and Performance Management* 71: 445–76. [\[CrossRef\]](#)
- Le, Minh-Hieu, and Wen-Min Lu. 2022. An integrated multiple objective decision making approach for exploring the competitiveness of pharmaceutical multinational enterprises. *Annals of Operations Research*. [\[CrossRef\]](#)
- Li, Kate, Mona Al-Amin, and Michael D. Rosko. 2023. Early financial impact of the COVID-19 pandemic on US Hospitals. *Journal of Healthcare Management* 68: 268–83. [\[CrossRef\]](#)
- Mansory, Ali, Ebrahimi Naser, and Morteza Ramazani. 2014. Ranking of Companies based on TOPSIS-DEA Approach Methods (Case Study of Cement Industry in Tehran Stock Exchange). *Pakistan Journal of Statistics and Operation Research* 10: 189–204. [\[CrossRef\]](#)
- Mardani, Sheida, Khalil Alimohammadzadeh, Ali Maher, Seyed Mojtaba Hoseini, and Kamyar Yaghmaeian. 2022. Capability of Different Multi-Criteria Decision-Making Techniques in the Performance Assessment of the Hospitals in Terms of Medical Waste Management. *Iranian Journal of Public Health* 51: 426. [\[CrossRef\]](#)
- Mogilevskaia, Anna. 2024. Nemocnice sa topia v dlhoch, zvýšené platy lekárov prehlbujú krízu. Podľa NKÚ je zdravotníctvo pred kolapsom. *Pravda*. Available online: <https://spravy.pravda.sk/domace/clanok/721377-nemocnice-sa-topia-v-dlhoch-zvysenie-platov-lekarov-prehlbuje-krizu-podla-nku-je-zdravotnictvo-pred-kolapsom/> (accessed on 3 September 2024).
- Moss, Charlie, Laura Anselmi, Marcello Morciano, Luke Munford, Jonathan Stokes, and Matt Sutton. 2023. Analysing changes to the flow of public funding within local health and care systems: An adaptation of the System of Health Accounts framework to a local health system in England. *Health Policy* 137: 104904. [\[CrossRef\]](#)
- Murphy, Kevin M., and Robert H. Topel. 2006. The value of health and longevity. *Journal of Political Economy* 114: 871–904. [\[CrossRef\]](#)
- Narayana, S. N. Sathiya, arthiban, P. Anbuechezian, and R. Dhanalakshmi. 2020. Assessment and Implementation of Lean and Green Supply Chain in Medium Scale Automobile Industries using AHP and Fuzzy TOPSIS. *Journal of Scientific & Industrial Research* 79: 720–26.
- Nijkamp, Peter, Piet Rietveld, and Henk Voogd. 2013. *Multicriteria Evaluation in Physical Planning*. Amsterdam: Elsevier.
- Oblak, Leon. 2014. Useful Methods for Diagnosing Environmental Conditions in the Workplace in Wood Industry. Paper presented at 7th International Scientific Conference on Position and Role of the Forecast Based Sector in the Green Economy, Zvolen, Slovakia, May 21–23.
- OECD. 2019. *State of Health in the EU: Slovakia: Country Health Profile 2019*. Paris: OECD Publishing. [\[CrossRef\]](#)
- OECD. 2021. *State of Health in the EU: Slovakia: Country Health Profile 2021*. Paris: OECD Publishing. [\[CrossRef\]](#)
- OECD. 2023. *State of Health in the EU: Slovakia: Country Health Profile 2023*. Paris: OECD Publishing. [\[CrossRef\]](#)
- Ortiz-Barrios, Miguel, Carlos Miranda-De la Hoz, Pedro López-Meza, Antonella Petrillo, and Fabio De Felice. 2020a. A case of food supply chain management with AHP, DEMATEL, and TOPSIS. *Journal of Multi-Criteria Decision Analysis* 27: 104–28. [\[CrossRef\]](#)
- Ortiz-Barrios, Miguel, Juan Cabarcas-Reyes, Alessio Ishizaka, Maria Barbat, Natalia Jaramillo-Rueda, and Giovanni de Jesús Carrascal-Zambrano. 2021. A hybrid fuzzy multi-criteria decision making model for selecting a sustainable supplier of forklift filters: A case study from the mining industry. *Annals of Operations Research* 307: 443–81. [\[CrossRef\]](#)
- Ortiz-Barrios, Miguel, Muhammet Gul, Pedro López-Meza, Melih Yucesan, and Eduardo Navarro-Jiménez. 2020b. Evaluation of hospital disaster preparedness by a multi-criteria decision making approach: The case of Turkish hospitals. *International Journal of Disaster Risk Reduction* 49: 101748. [\[CrossRef\]](#)
- Pamučar, Dragan S., Darko Božanić, and Aca Randelović. 2017. Multi-criteria decision making: An example of sensitivity analysis. *Serbian Journal of Management* 12: 1–27. [\[CrossRef\]](#)
- Petruška, Igor, Sylvia Jenčová, and Júlia Abu Zaid. 2019. Hodnotenie súkromných nemocníc pomocou metódy MDS. In *Predikčná analýza finančnej situácie nefinančných korporácií*. Edited by Sylvia Jenčová. Prešov: BookMan, pp. 82–86.
- Porter, Michael E., and Thomas H. Lee. 2013. The strategy that will fix health care. *Harvard Business Review* 91: 50–70.
- Prejmorean, Cornelia, and Simona Vasilache. 2009. Study regarding customer perception of healthcare service quality in Romanian clinics, based on their profile. *Amfiteatru Economic Journal* 11: 298–304.
- Proctor, Wendy, and Martin Drechsler. 2006. Deliberative multicriteria evaluation. *Environment and Planning C: Government and Policy* 24: 169–90. [\[CrossRef\]](#)
- Qorri, Ardian, Saranda Gashi, and Andrzej Kraslawski. 2022. A practical method to measure sustainability performance of supply chains with incomplete information. *Journal of Cleaner Production* 341: 130707. [\[CrossRef\]](#)
- Rahimi, Hamed, Mohammad Khammar-nia, Zahra Kavosi, and Marzieh Eslahi. 2014. Indicators of hospital performance evaluation: A systematic review. *International Journal of Hospital Research* 3: 199–208.
- Raipuria, Anil. 2020. An Analysis of the Different Types of Financial Management and Their Purposes. *International Journal for Research Publication and Seminar* 11: 122–28.
- Rhodes, Jordan. H., Tatiane Santos, and Gary Young. 2023. The early impact of the COVID-19 pandemic on hospital finances. *Journal of Healthcare Management* 68: 38–55. [\[CrossRef\]](#)
- Rocha, António, Ana Sara Costa, José Rui Figueira, Diogo Cunha Ferreira, and Rui Cunha Marques. 2021. Quality assessment of the Portuguese public hospitals: A multiple criteria approach. *Omega* 105: 102505. [\[CrossRef\]](#)



- Rouyendegh, Babak Daneshvar, Abdullah Yildizbasi, and Ibrahim Yilmaz. 2020. Evaluation of retail industry performance ability through integrated intuitionistic fuzzy TOPSIS and data envelopment analysis approach. *Soft Computing* 24: 12255–66. [\[CrossRef\]](#)
- Saeed, Nasir, Haewoon Nam, Mian Imtiaz Haq, and Dost Bhatti Muhammad Saqib. 2018. A Survey on Multidimensional Scaling. *ACM Computing Surveys (CSUR)* 51: 1–25. [\[CrossRef\]](#)
- Sagarra, Marti, Cecilio Mar-Molinero, and Tommaso Agasisti. 2017. Exploring the efficiency of Mexican universities: Integrating data envelopment analysis and multidimensional scaling. *Omega* 67: 123–33. [\[CrossRef\]](#)
- Sendek, Stanislav. 2014. Efficiency evaluation of hospitals in the environment of the Slovak Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 62: 697–706. [\[CrossRef\]](#)
- Sendek, Stanislav, Zuzana Svitáľková, and Katarína Angelovičová. 2015. Efficiency evaluation of hospitals in the environment of the Czech and Slovak Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 63: 2109–18. [\[CrossRef\]](#)
- Shafii, Milad, Sima Rafiei, Fatemeh Abooei, Mohammad Amin Bahrami, Mojtaba Nouhi, Farhad Lotfi, and Khatere Khanjankhani. 2016. Assessment of service quality in teaching hospitals of Yazd University of Medical Sciences: Using multi-criteria decision making techniques. *Osong Public Health and Research Perspectives* 7: 239–47. [\[CrossRef\]](#)
- Soares, Adeilson Barbosa, Adriano Alves Pereira, and Selma Terezinha Milagre. 2017. A model for multidimensional efficiency analysis of public hospital management. *Research on Biomedical Engineering* 33: 352–61. [\[CrossRef\]](#)
- Sørensen, Kristine, Jürgen M. Pelikan, Florian Röthlin, Kristin Ganahl, Zofia Slonska, Gerardine Doyle, James Fullam, Barbara Kondilis, Demosthenes Agrafiotis, Ellen Uiters, and et al. 2015. Health literacy in Europe: Comparative results of the European health literacy survey (HLS-EU). *The European Journal of Public Health* 25: 1053–58. [\[CrossRef\]](#)
- Štefko, Robert, Beata Gavurova, and Kristina Kocisova. 2018. Healthcare efficiency assessment using DEA analysis in the Slovak Republic. *Health Economics Review* 8: 6. [\[CrossRef\]](#)
- Štefko, Róbert, Sylvia Jenčová, and Petra Vašaničová. 2020. The Slovak Spa Industry and Spa Companies: Financial and Economic Situation. *Journal of Tourism and Services* 20: 28–43. [\[CrossRef\]](#)
- Štefko, Róbert, Sylvia Jenčová, Eva Litavcová, and Petra Vašaničová. 2017. Management and funding of the healthcare system. *Polish Journal of Management Studies* 2: 266–77. [\[CrossRef\]](#)
- Thakkar, Jitesh J. 2021. *Multi-Criteria Decision Making*. Singapore: Springer.
- Tong, Lizhong, Zhongmin Pu, and Jizheng Ma. 2019. Maintenance supplier evaluation and selection for safe and sustainable production in the chemical industry: A case study. *Sustainability* 11: 1533. [\[CrossRef\]](#)
- Türegün, Nida. 2022. Financial performance evaluation by multi-criteria decision-making techniques. *Heliyon* 8: e09361. [\[CrossRef\]](#)
- Ucuncu, Tutku, Kadri Cemil Akyuz, İlker Akyuz, Bahadır Çağrı Bayram, and Nadir Ersen. 2018. Evaluation of financial performance of paper companies traded at BIST with TOPSIS method. *Kastamonu University Journal of Forestry Faculty* 18: 92–98. [\[CrossRef\]](#)
- Uygurtürk, Hasan, and Turhan Korkmaz. 2012. The determination of financial performance with TOPSIS multiple criteria decision making method: An application on basic metal industry enterprises. *Eskişehir Osmangazi University Journal of Economics and Administrative Sciences* 7: 95–115.
- Vasanicova, Petra, Sylvia Jencova, Beata Gavurova, and Radovan Bacik. 2022. Coopetition of European Union countries within destination management. *Journal of Tourism and Services* 13: 71–89. [\[CrossRef\]](#)
- Wang, Chia-Nan, Ying-Fang Huang, I-Fang Cheng, and Van Thann Nguyen. 2018. A multi-criteria decision-making (MCDM) approach using hybrid SCOR metrics, AHP, and TOPSIS for supplier evaluation and selection in the gas and oil industry. *Processes* 6: 252. [\[CrossRef\]](#)
- Wang, Yu-Jie. 2014. The Evaluation of financial performance for Taiwan container shipping companies by Fuzzy TOPSIS. *Applied Soft Computing* 22: 28–35. [\[CrossRef\]](#)
- Wang, Zheng-Xin, and Yan-Yu Wang. 2014. Evaluation of the provincial competitiveness of the Chinese high-tech industry using an improved TOPSIS method. *Expert Systems with Applications* 41: 2824–31. [\[CrossRef\]](#)
- Weerathunga, P. R., Xiaofang Cheng, W. H. M. S. Samarathunga, and K. M. M. C. B. Kulathunga. 2020. Application of Entropy Based Topsis in Analysis of Sustainability Performance of Sri Lanka Hotels. *Journal on Innovation and Sustainability RISUS* 11: 100–8. [\[CrossRef\]](#)
- Wu, Wen-Hsiang, Chin-Tsai Lin, and Kua-Hsin Peng. 2011. Compare strategy of different hospitals on the global budget system. *Journal of Information and Optimization Sciences* 32: 169–87. [\[CrossRef\]](#)
- Zaim, Selim, Nuzamettin Bayyurt, Ali Turkyilmaz, Nihat Solakoglu, and Halil Zaim. 2008. Measuring and evaluating efficiency of hospitals through total quality management: A multi-criteria data envelopment analysis model. *Journal of Transnational Management* 12: 77–97. [\[CrossRef\]](#)
- Zopounidis, Constantin, Emiliós Galariotis, Michael Doumpos, Stavroula Sarri, and Kostas Andriopoulos. 2015. Multiple criteria decision aiding for finance: An updated bibliographic survey. *European Journal of Operational Research* 247: 339–48. [\[CrossRef\]](#)

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.