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**MATEJ BEL
UNIVERSITY**
IN BANSKÁ BYSTRICA

Jana Špírková

SUSTAINABILITY INDEX OF PENSION SYSTEMS

2025

 **BELIANUM**

FACULTY OF ECONOMICS

MATEJ BEL UNIVERSITY IN BANSKÁ BYSTRICA



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INTRODUCTION

The issue of sustainability of pension systems is currently a hot topic across global economies, including Slovakia. Almost all countries are facing challenges in financing pension schemes, which are under pressure not only due to demographic changes.

One of the key documents providing a comprehensive international comparison of pension systems since 2009 is the Mercer CFA Institute Global Pension Index, in which Mercer, the CFA Institute and the Monash Centre for Financial Studies assess pension systems in approximately 49 countries around the world, Mercer [2009] - Mercer [2023]. The number of countries has changed in some years, some are not included in the assessment, others are being added. The overall pension index consists of three sub-indices, namely the adequacy sub-index, the sustainability sub-index and the completeness sub-index.

The main reason for writing this monograph was the absence of Slovakia in the evaluation of the aforementioned index. A secondary motivation was to determine Slovakia's position in comparison with selected European countries. Lastly, the third motivation was to examine whether our perception of the significance of individual indicators aligns with Mercer's, or if there are notable differences. Although the monograph focuses solely on the sustainability sub-index, we use the term sustainability index consistently throughout the text.

This monograph aims to compute Slovakia's sustainability index by applying four distinct weighting methods to the nine contributing indicators and to analyze and compare the resulting values with those of selected European countries.

The sustainability index considers key demographic and economic indicators that are essential for the long-term funding of pension systems. Specifically, it includes factors like the old-age dependency ratio, retirement age, savings rate, government debt levels, public pension spending, and real economic growth. Based on these indicators, sustainability is evaluated as the system's capacity to secure long-term financing without requiring frequent interventions or reforms that might impact the quality of the pensions

delivered.

The current Slovak pension system is built on three pillars, each of which contributes to different aspects of sustainability. The first pillar represents a pay-as-you-go system administered by the Social Insurance Institution and is dependent on ongoing contributions from current workers. Its stability is closely linked to demographic trends, which puts pressure on the search for alternative solutions for sustainability. The second pillar is based on the principle of funded savings and represents privately managed funds which are, however, sensitive to capital market developments. The third, voluntary pillar, serves as a supplement to the basic income at retirement age, contributing to the diversification of sources of retirement income.

When comparing the sustainability index of the Slovak pension system with other countries, we can say that Slovakia scores below the average of selected European Union countries, with an overall average of 45.22 points. This means that the Slovak pension system in the area of sustainability falls into category D on a scale from A to E, with a score range of 35 to 50 points, and thus has "weaknesses and major deficiencies that need to be addressed; without these improvements, its sustainability is questionable." Mercer [2023].

In the context of current developments, monitoring the sustainability of pension systems is essential. The Organisation for Economic Co-operation and Development (OECD) contributes to this area with its Global Pension Statistics project, which since 2002 has provided an overview of key indicators of pension systems and allowed cross-country comparisons. This project provides a valuable tool for monitoring and evaluating pension policies to ensure their long-term sustainability.

This monograph explores the concept of pension sustainability by constructing and analysing a sustainability index. The first chapter begins by identifying and explaining nine key indicators that influence the long-term viability of pension systems. These include demographic, economic, financial and governance-related factors, such as pension asset levels, life expectancy at retirement and labour force participation, as well as environmental, social and governance (ESG) issues. Each indicator is analysed in terms of its relevance and impact on pension system sustainability.

After identifying the indicators, the second chapter focuses on methods used to determine their relative importance or weights. It presents various weighting methodologies, including Exact and Approximate Saaty's methods, the Thurstone method of paired comparisons, and the Best-Worst method. These techniques quantify the influence of each indicator on the overall sustainability index.

The third chapter presents the calculation of the sustainability index based on the weighted indicators. This methodology is applied to evaluate the pension system of Slovakia. A comparative analysis is also conducted with selected European countries to provide broader insights.

The results highlight the strengths and vulnerabilities of different systems, informing evidence-based policy recommendations. The monograph concludes by summarising the findings and their implications for future pension reforms. It also discusses limitations and areas for further research. Supporting materials, including figures, tables, bibliographic references and an appendix, are provided at the end of the text. This structured approach ensures a comprehensive and comparative view of pension sustainability. The study aims to support policymakers, researchers and institutions in their efforts to create resilient pension systems in an ageing Europe.

The monograph uses data valid as of November 2024. The monograph is written in the typographic system L^AT_EX in the online editor Overleaf.

Jana Špírková

Chapter 1

SUSTAINABILITY INDEX INDICATORS

The sustainability of pension systems depends on a wide range of economic, demographic and societal factors that interact to influence the ability of countries to ensure the stability of pension incomes over the long term. One important indicator of sustainability is the share of the working-age population actively saving in private pension funds. This indicator influences the level of pension assets, i.e. the total amount of savings available for future generations of pensioners. At the same time, a key aspect in this context is life expectancy at retirement age, which, in conjunction with demographic projections, poses challenges for the long-term stability of pension systems.

Demographic factors such as fertility and life expectancy are key in the context of pension systems, as they determine to what extent a country is able to sustain working-age population growth, which is important for the financing of pay-as-you-go pension systems. In addition, the labour force participation rate for 55-64 year olds and the employment rate for over-65s are important factors affecting the overall economic contribution of older citizens to the pension system and hence the long-term viability of pension funding.

From an economic perspective, mandatory funded contributions within the old-age pension savings system are vital for maintaining pension scheme sustainability, as they support the continuous buildup of assets in individuals' personal accounts. Additionally, government debt and public spending on pensions are key elements that significantly influence the financial stability of the entire system. While rising public debt may pose a risk, high public pension expenditure is essential in many countries to maintain an adequate standard of living for pensioners. Another important aspect is access to part of the savings earmarked for retirement, which allows savers to use part of the accumulated funds before retirement age, which can have various implications

for the long-term sustainability of the system.

In terms of macroeconomic indicators, real economic growth has a major impact on the income of pension schemes and on the ability of the economy to support its ageing population. Equally important is ESG (Environmental, Social, and Governance) governance, which contributes to the responsible management of pension assets in line with sustainability criteria, an increasingly important aspect in the development of pension systems at a global level. Directive (EU) 2016/2341 of the European Parliament and of the Council of 14 December 2016 focuses on the activities and supervision of occupational pension institutions. One of the key aspects of this Directive is the requirement for Member States to ensure that pension funds disclose information on environmental, social and governance (ESG) management factors that influence their investment decisions.

This chapter focuses on a detailed analysis of these factors and how they interrelate with the sustainability of pension schemes. It emphasises the development of sustainable strategies that take into account demographic trends, financial stability and responsible pension fund management.

Although at the time of writing the overall pension index Mercer [2024] has already been published, the monograph uses data from Mercer [2023] in the analysis, as all the necessary data for Slovakia from 2024 have not yet been officially published. For the sake of compatibility of our results, all basic questions of the indicators are taken exactly from Mercer [2023].

In the following sections, we write in detail about the individual indicators of the sustainability index and recall the basic questions that represent them. We turn our attention to indicators I1 to I9 - the share of the working-age population saving in private pension funds, the level of pension assets, life expectancy at retirement age, funded mandatory contributions, the employment rate at ages 55-64, government debt and public pension costs, access to a portion of savings, real economic growth, and environmental, social, and government management.

1.1 Indicator I1 - Share of the population of working age who save in private pension funds

The U1 indicator provides insight into how actively the working population is involved in securing their retirement through private means, beyond the state system. Greater participation in private savings can enhance individuals' long-term financial security in retirement and simultaneously ease the burden on public pension systems.

The basic question of this indicator is: What proportion of the working-age population contributes to private pension funds?

Private pension plans, including pension plans for public sector employees

and the military, are an important pillar in all retirement income schemes. A higher coverage ratio between the workforce and savings in private pension companies therefore increases the likelihood that the overall retirement income system will be sustainable in the future as funding continues and the level of retirement assets increases over time. Saving in private pension companies ensures the stability of the pension system as it relieves the burden on government expenditure. It is, therefore, important that the share of the working-age population in private schemes is as high as possible.

According to OECD [2024a], the working age population is defined as the population aged 15 to 64. Indicator I1 measures the share of the working-age population in the total population.

The publication *Pensions at a Glance* [2019] states that total participation in capitalisation pensions as a percentage of the working-age population in Slovakia was approximately 38%. However, this value has been rising sharply in recent years.

Individuals can participate in an occupational pension plan or voluntarily contribute to a pension plan, which may be encouraged by government policies.

Act No. 595/2003 Coll. [2003] - The Income Tax Act, § 11 - Non-taxable parts of the tax base, paragraphs (8), (9) and (10), provides that contributions to a supplementary pension savings plan demonstrably paid in a tax year for those who meet the conditions set out in this Act form a non-taxable part of the tax base.

Remark 1.1. For further information, we quote the wording of the above paragraphs from the Income Tax Act, Act No. 595/2003 Coll. [2003]:

- (8) Contributions to a pan-European personal pension product under a special regulation, ^{34a)} contributions to a pan-European personal pension product Act No. 129/2022 Coll. [2022] abroad of the same or comparable type, contributions to supplementary pension savings under a special regulation ³⁵⁾ Act No. 650/2004 Coll. [2004] and contributions to supplementary pension savings abroad of the same or comparable type are also a non-taxable part of the tax base.
- (9) The taxpayer's contributions to a pan-European personal pension product and the taxpayer's contributions to supplementary pension savings under paragraph (8) may be deducted from the tax base in the amount in which they are demonstrably paid in the tax period, up to a maximum of EUR 180 per year in the aggregate; in calculating the aggregate of the saver's contributions to the pan-European personal pension product (Information on Act No 129/2022 Coll. [2023] and the participant's contributions to the supplementary pension savings, the procedure under § 4(1)(a) shall apply § 4 paragraph 3).

- (10) For the tax-free part of the taxable amount to apply under paragraph 8, the following conditions must be met simultaneously:
- (a) the contributions referred to in paragraph (8) were paid by the taxpayer under a participation contract entered into after 31 December 2013, or under an amendment to a participation contract which includes the cancellation of a benefit plan, or under a contract for a pan-European personal pension product under a special regulation, ^{64a}),
 - b) the taxpayer does not have another participation contract under a special regulation, ³⁵) which does not meet the conditions referred to in point (a).

Remark 1.2. The working-age population refers to the number of people within a certain age group who are considered to be potential labour force participants. This age group usually includes individuals who are over a certain minimum age, for example, 15, 18 or 20, and under a certain maximum age, for example, 65, 70 or 75, depending on the country or region, SO SR [2024a]. As already mentioned, within OECD [2024a], the working age population is defined as the population aged 15 to 64, i.e., the sum of all persons of working age who are employed and those who are unemployed.

The economically active population, on the other hand, refers to the part of the working-age population that actually participates in the labour force by being either employed or actively seeking employment. This includes people who are currently employed as well as those who are unemployed and actively looking for work. According to SO SR [2023], the economically active population represents all persons aged between 15 and 89 who are either in employment or unemployed.

While the working-age population refers to all individuals who are of a certain age and potentially able to work, the economically active population represents the subset of the working-age population that actually participates in the labour market. It is important to note that some people in the working-age population may not be economically active due to factors such as disability, retirement or the decision not to work for personal reasons.

Figure 1.1 shows the share of the working-age population in the total population in Slovakia for the years under review. Table 1.1 shows the total population and the working-age population in Slovakia aged between 15 and 64 years as of 31 December of the respective year.

In Table 1.2, we report the specific number of savers in Pillar II and Pillar III in 2020-2023 according to MLSAaF [2024a]. We do not have data that tells us exactly how many savers are saving in both Pillar II and Pillar III simultaneously. Such common databases are not yet available, so we assume that those who save in Pillar II also save in Pillar III. Thus, we use the number of savers in Pillar II in the share of the working-age population saving in

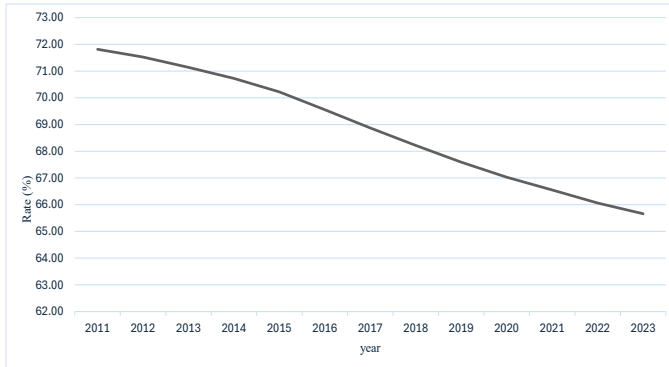


Figure 1.1: Rate of the working-age population in the total population in Slovakia

Source: the author according to OECD [2024a].

Table 1.1: Total population and working-age population in Slovakia aged 15-64 as of 31 December of the year concerned

year	share of working age population in total population (%)	working-age population	population
2020	67.03	3,659,463	5,459,781
2021	66.55	3,616,958	5,434,712
2022	66.06	3,586,272	5,428,792
2023	65.66	3,561,849	5,424,687

Source: the author according to SO SR [2024a] and SO SR [2024b].

private pension funds. The share of savers in private pension funds to the working-age population is reported in column 5 of Table 1.2.

According to Mercer [2023], and based on the recalculation of the interval (15, 80)%, we assign to the I1 variable in the observed years the values shown in Table 1.3.

Table 1.2: Number of the working-age population aged 16-64 as of 31 December of the year concerned, number of savers in the pillars II and III of pension saving and their share

year	working-age population	Pillar II	Pillar III	share in Pillar II (%)	share in Pillar III (%)
2020	3,659,463	1,626,177	861,344	44.44	23.54
2021	3,616,958	1,680,220	904,987	46.45	25.02
2022	3,586,272	1,736,378	948,281	48.42	26.44
2023	3,561,849	1,813,216	990,537	50.91	27.81

Source: the author according to MLSAaF [2024a], MLSAaF [2024b] and OECD [2024a]

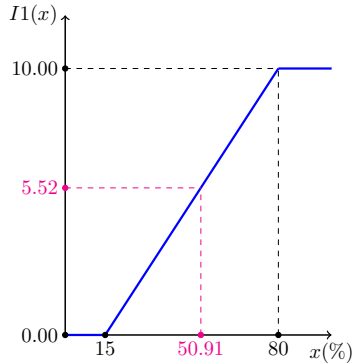


Figure 1.2: Value of indicator I1 for 2023

Source: the author according to Mercer [2023]

Table 1.3: Values of indicator I1 in Slovakia for the monitored years

year	2020	2021	2022	2023
share of savers (%)	44.44	46.45	48.42	50.91
I1 indicator value	4.53	4.84	5.14	5.52

Source: the author

1.2 Indicator I2 – Level of pension assets

The ratio of pension assets to gross domestic product (GDP) serves as a crucial measure of the financial stability of pension systems. These assets may take various forms, including private pension plans, public pension reserve funds, protected book reserves, and pension insurance policies. Representing them as a percentage of GDP provides a clearer picture of how stable and sustainable the financial resources for pension provision are.

To ensure stable pension payouts, pension assets must be adequately high in relation to GDP. Insufficient savings can jeopardize the long-term sustainability of pension systems, both for the state and insurance providers. Therefore, increasing pension assets in both private and public funds is essential to support the financial independence of future retirees.

The core question this indicator addresses is: What proportion of GDP is represented by pension assets held in private pension plans, public pension reserve funds, protected book reserves, and pension insurance contracts?

ICPF statistics (Insurance Companies and Pension Funds) are a valuable tool for tracking the level of pension assets. These statistics provide important data on the financial assets and liabilities of insurance companies and pension funds, and help to analyse how pension funds are funded and what risks they face, NBS [2023].

Since 2016, ICPF statistics also include data on branches of insurance companies from other EU member states, which increases the comprehensiveness and accuracy of the available data. The aggregated quarterly data within the ICPF statistics allow us to track trends in the volume of pension assets as well as changes in the investment structure of these funds. The data for the years we work with are the aggregated quarterly data entered in Table 1.4.

Table 1.4: Financial assets of pension funds and GDP of Slovakia for the years under review

year	2020	2021	2022	2023
Financial assets of pension funds (mil. EUR)	9,246.35	10,872.90	7,628.11	11,593.22
GDP (mil. EUR)	93,444.10	100,255.70	109,645.20	122,156.20

Source: the author according to Gross domestic product [2024], Private pension assets of Slovakia [2024].

From the perspective of the sustainability of the pension system, it is important that pension funds continuously increase their assets in line with GDP growth. Increasing pension assets reduces the pressure on public finances and contributes to the long-term stability of the social security system.

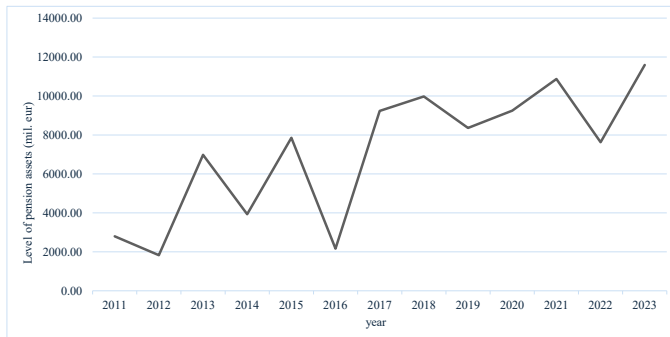


Figure 1.3: Slovakia's level of pension assets

Source: the author according to Private pension assets of Slovakia [2024].

The level of pension assets of the LPA as a percentage of GDP is determined by the formula

$$\text{LPA} = \frac{\text{financial assets of pension funds}}{\text{GDP}} \times 100\%. \quad (1.1)$$

According to Mercer [2020] and Mercer [2021], a linear relationship between the respective level of pension assets from 0% to 175% and a scale from 0 to 10 points was used to determine the value of the I2 indicator, but is no longer used from 2022. Based on Mercer [2023], more credit is given for increases at lower asset levels than at higher levels, as these asset levels will provide relatively larger improvements in sustainability.

According to Mercer [2023], the size of assets earmarked for future pensions varies considerably around the world, reflecting the relative importance of funded pension schemes. In addition, many countries are undergoing a reform process that is expected to increase asset levels over many decades. In these cases, Mercer expects the value of this indicator to increase gradually in the future.

Remark 1.3. Linear scoring approach between 0% and 175% is no longer used. According to Mercer [2022], more credit is given for increases at the lower levels of assets than at the higher levels as these gains will provide relatively greater improvements in sustainability. In our view, this adjustment was not even necessary as it causes the indicator score to increase by 0.5 points on average. This situation does not significantly affect the overall score of the countries. Rather, in a negative sense, it distorts comparisons of scores

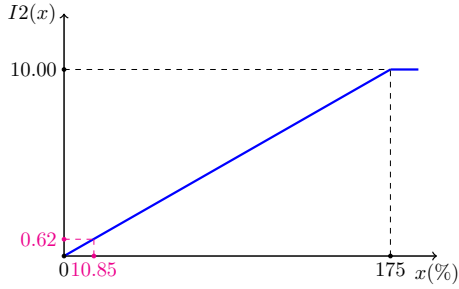


Figure 1.4: Value of indicator I2 for 2021
Source: the author according to Mercer [2021]

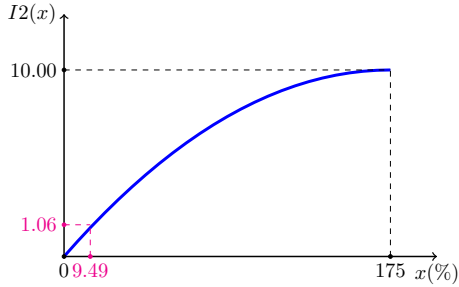


Figure 1.5: Value of indicator I2 for 2022, 2023
Source: the author according to Mercer [2023]

Table 1.5: Indicator I2 values for the years under review

year	2020	2021	2022	2023
level of pension assets as % of GDP	9.90	10.85	6.96	9.49
I2 indicator value w.r.t. the linear dependence	0.56	0.62	0.06	0.54
I2 indicator value w.r.t. the quadratic dependence	1.10	1.20	0.78	1.06

Source: the author

for this indicator over the years. Moreover, it is not clear from Figure 15 of Mercer [2022] whether the peak of the parabola is at the 175% point. We use a quadratic function that passes through the point $[0, 0]$ and has a vertex at $[175, 10]$.

1.3 Indicator I3 – Life expectancy at retirement age

Life expectancy at retirement age is a key factor in pension and social security planning. It fluctuates annually due to various influences such as healthcare quality and living conditions. As life expectancy is expected to keep rising, pension systems will increasingly be challenged to fund longer retirement periods.

The old-age dependency ratio, which reflects the proportion of pensioners to the working-age population, is projected to increase significantly by 2050. In the updated forecast by Mercer [2022], this ratio is shifted to 2052, providing a longer horizon to analyse demographic changes.

The estimated Total Fertility Rate (TFR) is another important factor in the long-term sustainability of the pension system. Under Mercer [2021]'s original assumptions, the TFR was examined for the period 2015-2020, but of course under Mercer [2023] this analysis has been updated for the period 2021-2025 to better reflect current fertility trends and their impact on future population trends.

The basic questions for determining the value of this indicator are:

I3a What is the current life expectancy at retirement age?

I3b What is the life expectancy at expected retirement age in 2053?

I3c What is the projected old-age dependency ratio in 2050? According to Mercer [2023], this question is modified: What is the projected old-age dependency ratio in 2053?

I3d What is the estimated Total Fertility Rate - TFR for 2021-2025? .
According to Mercer [2023], these questions are changed from year to year based on the respective observation period.

We address each question individually in order to calculate the I3 indicator score.

To I3a The life expectancy according to SO SR [2024f] for a 63-year-old individual in the observed years is given in Table 1.6 and according to Mercer [2023] on a 10-point scale from 18 to 28 years of age, its values are consecutively assigned. These values are determined as a linear relationship based on Figure 1.7. Recall that the original methodology according to Mercer [2022] was determined using years from 13 to 23.

To I3b Based on Eurostat [2023a] data, the life expectancy prediction for a 63-year-old individual in 2053 is 21.60 years. On the same scale as for I3a, I3b is assigned a value of 6.40, see Table 1.7.

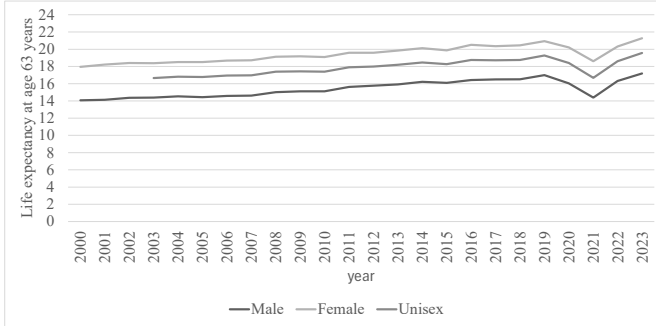


Figure 1.6: Life expectancy for an individual aged 63 until 2023.

Source: the author according to SO SR [2024e]

To I3c The data are listed in Table 1.8. The old-age dependency ratio OADR is given by the formula

$$\text{OADR} = \frac{\text{population aged } 65+}{\text{population aged } [15, 64]} \times 100\%. \quad (1.2)$$

Table 1.6: Indicator I3a values for the years under review

year	2020	2021	2022	2023
life expectancy at age 63 years	18.40	16.68	18.61	19.56
value of the indicator according to Mercer [2023]	9.60	10.00	9.39	8.44

Source: the author

Eurostat [2023b] gives a predicted old-age dependency ratio for 2053 of 52.90%, and thus we assign a score of 4.28 for I3c on the same scale.

Table 1.7: Values of indicator I3b for the years under review

year	2020	2021	2022	2023
Predicted life expectancy at age 63 in 2053 value of the indicator	21.55	21.55	21.60	21.60
	6.45	6.45	6.40	6.40

Source: the author

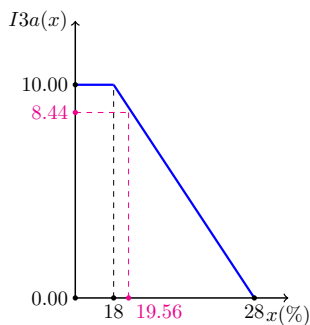


Figure 1.7: Value of indicator I3a for 2023

Source: the author according to Mercer [2023]

Table 1.8: Values of indicator I3c for the years under review

year	2020	2021	2022	2023
old-age dependency ratio				
OADR at 2053 (%)	51.40	51.40	53.20	52.90
value of the indicator	4.65	4.65	4.20	4.28

Source: the author

To U3d Total fertility rate (TFR) is the average number of live births per woman over her entire reproductive period (15-49 years), maintaining the fertility level of the year of interest and for assuming zero mortality. The estimated total fertility rate for Slovakia is determined as an average value for the period 2021-2025. Based on Eurostat [2023c] and World population review [2024], the average fertility rates for Slovakia in each of the years of interest are entered in Table 1.9, so we assign values to it using the scale shown in Figure 1.9.

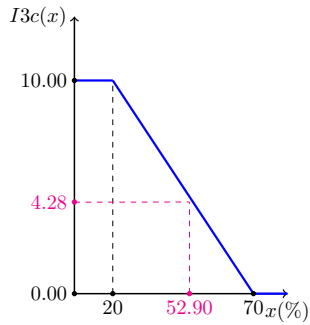


Figure 1.8: Value of indicator I3c for 2023
Source: the author according to Mercer [2023]

Table 1.9: Indicator I3d values for the years under review

year	2020	2021	2022	2023
total fertility rate for the years 2021–2025	1.52	1.52	1.61	1.60
value of the indicator	3.47	3.47	4.07	4.00

Source: the author

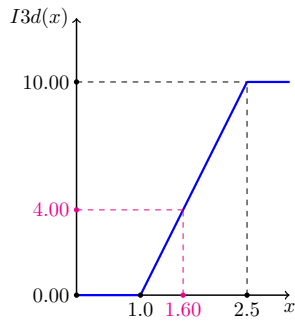


Figure 1.9: I3d indicator value for 2023
Source: the author according to Mercer [2023]

Remark 1.4. Directive 2004/113/EC, commonly referred to as the "Gender Directive", is European Union legislation that aims to ensure equal treatment regardless of gender, particularly regarding access to goods and services. Directive 2004/113/EC was adopted in 2004 and establishes rules to eliminate discrimination on the grounds of sex, in particular in the provision of insurance products and other financial services. One of the main changes brought about by the Directive was the prohibition of the use of gender as a factor in the calculation of insurance premiums and claims from December 2012.

The Directive stipulated that such differences are not in line with the principle of equality and can be considered discriminatory. Since December 2012, insurers are no longer allowed to use gender as a factor in calculating the prices of insurance products.

The implementation of this Directive has notably influenced the insurance market, requiring insurers to revise their risk assessment and pricing strategies. From the consumer's standpoint, the response has been mixed. Some individuals—particularly women—may have faced higher premiums for certain insurance products, while men may have seen reductions. Nevertheless, the Directive has played a role in promoting gender equality and enhancing transparency within the insurance sector.

Although the Directive primarily addresses issues of equal access to services and insurance products, in a broader context it promotes the debate on gender equality in all areas of life.

Remark 1.5. Current research shows that sustainability is becoming a key issue in pension policy and requires continuous attention in both academic and policy circles. Contributions by renowned authors such as Berstein and Morales Sepúlveda [2021], Zelinová and Sakálová [2023], who analyse the impact of longevity insurance on pension systems, contribute to the understanding of sustainability challenges. The analysis of pension reforms in Europe by Hinrichs [2021] plays a significant role in shaping national policy decisions. Furthermore, actuarial research in pension modelling provides a vital contribution to understanding and assessing the sustainability of pension systems, as highlighted by Krčová et al. [2022], Sakálová and Zelinová [2023], and Špirková et al. [2023].

1.4 Indicator I4 – Funded mandatory contributions

The amount of mandatory contributions toward future pension benefits, expressed as a percentage of the average annual salary, plays a key role in maintaining the financial stability of the pension system. These contributions typically include compulsory payments from both employees and employers and are used to fund future pension entitlements. They may support public schemes, such as social security contributions, as well as private pension funds, thereby diversifying the sources of pension financing.

In Slovakia, the amount of compulsory contributions to old-age pension savings is set by Act No 43/2004 Coll. on old-age pension savings. According to this Act, contributions are divided according to different rates, which are set out in Part 3, Section 22, and are specified precisely for each category of contributor. Both the employee's and the employer's contributions are then deposited in a pension fund which is intended to pay pensions in the future.

This funding model contributes to the sustainability of the pension system by ensuring that pension contributions are made regularly during an individual's active working life. The level of contributions is expressed as a percentage of wages, which means that rising wages also lead to an increase in contributions to the pension scheme.

Legislation concerning the second pillar of pension savings in Slovakia has undergone several changes since its introduction, which contributes to a certain instability of this system. Pillar II, introduced as part of the pension system in 2005, was originally intended to provide an additional source of pension income by transferring part of the mandatory contributions of employees and employers to individual accounts in private pension management companies. However, despite the original intention, the rules of Pillar II have changed many times since then, raising questions and doubts about its long-term stability and predictability.

One of the most significant changes has been the several changes to the rate of compulsory contributions that employees pay into Pillar II. These rates have varied according to government policy, adjusting the proportion of contributions that go into the public Pillar I and the private Pillar II. These changes have a direct impact on the amount that savers can expect to receive in retirement.

Another source of instability is the periodic opening and closing of Pillar II, where the government allows savers to decide whether to remain in Pillar II or return to a purely public pension scheme. These "windows" for withdrawal or re-enrolment disrupt the continuity of savings and can affect savers' returns. These interruptions or early withdrawals from pension accounts reduce capital accumulation.

Frequent changes in legislation also affect the investment strategies of pension management companies that manage savers' assets. Constant rule changes and investment restrictions mean that pension management com-

panies often have to adjust their portfolios, which can affect the long-term returns of the funds. For example, the structure of permitted assets, limits on risky investments or requirements for conservative portfolios are changing, creating uncertainty in the planning of retirement strategies.

The impact of unstable legislation on Pillar II means that savers are often unclear about the returns they can expect and the extent to which their savings will appreciate by retirement age. The result is uncertainty among future pensioners who are unsure whether they will have a sufficiently stable source of income to ensure a good quality of life in old age. This situation also raises questions about the long-term sustainability and credibility of Pillar II in the eyes of savers and the wider public.

The key question for determining the value of indicator I4 is: What is the amount of mandatory contributions that are earmarked for future pension benefits (i.e. funded), expressed as a percentage of the annual wage for a full-time middle-income earner? This may include employer and/or employee mandatory contributions paid into funded public benefits (i.e., Social Security) and/or private sector retirement benefits.

Act No. 43/2004 Coll. on old-age pension savings and on amendment and supplementation of certain acts and Act No. 595/2003 Coll. [2003] states the rate of compulsory contributions. In Part 3 - Contributions to retirement pension savings, in Section 22 - Rate of compulsory contributions, the following rates are given under the individual letters:

- e) in 2020, 5% of the assessment base,
- f) in 2021, 5.25% of the assessment base,
- g) in 2022 and 2023, 5.50% of the assessment base,
- h) in 2024 and subsequent years 4.00% of the assessment base.

According to Mercer [2023], by transforming the $[0, 12]\%$ scale into a 10-point score scale, which is shown in Figure 1.11, the indicator I4 - Funded compulsory contributions is assigned the values shown in Table 1.10.

Table 1.10: Indicator I4 values for the years under review

year	2020	2021	2022	2023
rate of compulsory contributions (%)	5.00	5.25	5.50	5.50
Indicator value I4	4.17	4.38	4.58	4.58

Source: the author according to Mercer [2023]

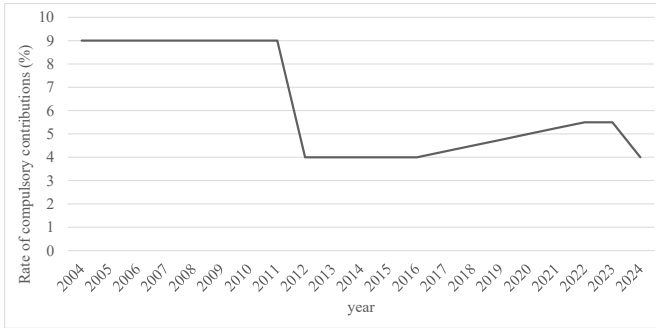


Figure 1.10: Rate of compulsory contributions in old-age pension savings
 Source: author based on Act No. 43/2004 Coll. [2004]

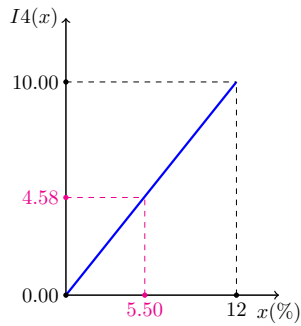


Figure 1.11: Indicator value $I4$ for 2023
 Source: the author according to Mercer [2023]

1.5 Indicator I5 – Labor force participation rate for ages 55 to 64

The employment rate among individuals aged 55–64 serves as an important measure of older adults’ active involvement in the workforce and their financial self-sufficiency prior to retirement. This age group often encounters barriers such as age-related discrimination and health issues, which can limit their job opportunities.

Nonetheless, many older workers continue to work either for financial reasons or personal fulfillment. Increasing employment in this age group is vital for ensuring the sustainability of pension systems and supporting the broader economic stability of the country.

The employability of older workers abroad often varies depending on the country and its legislation, labour market culture and pension system.

The basic questions for determining the value of the I5 indicator are:

I5a What is the employment rate for people aged 55-64?

I5b What is the employment rate for people aged 65 and over?

The employment rate, or in other words, the labour force participation rate LFPR, is calculated according to the relationship

$$\text{LFPR} = \frac{\text{labour force}}{\text{working age population}} \times 100\%, \quad (1.3)$$

where

- labour force is composed of active people who are currently working and people who are actively seeking employment. These people are able to work and contribute to the economic performance of a country.
- Working-age population is the population aged 15-64.

Based on ILO [2024] and SO SR [2024c] data, we report the employment rate for 55-64 year olds in Table 1.11. According to Mercer [2023] scaling from (40-80)% to a 10-point scale, we assign the corresponding values also reported in Table 1.11.

Table 1.11: Indicator I5a values for the years under review

year	2020	2021	2022	2023
employment rate for aged 55-64 years (%)	58.30	60.60	64.10	66.60
I5a indicator value	4.58	5.15	6.03	6.65

Source: the author according to Mercer [2023] and SO SR [2024c]

For ages 65 and over, employment rates and the corresponding indicator scores are shown in Table 1.12.

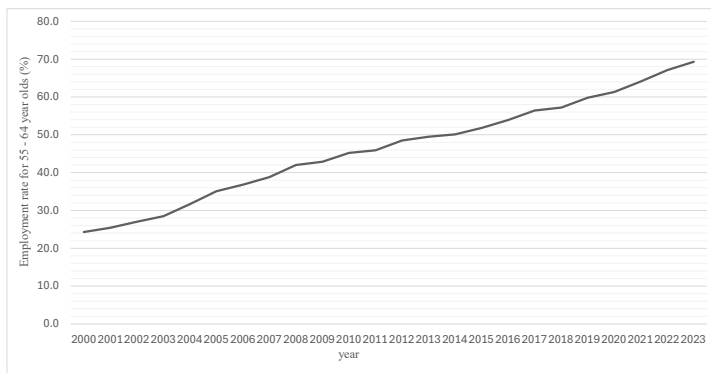


Figure 1.12: Employment rate for 55-64 year olds in Slovakia
Source: the author according to ILO [2024]

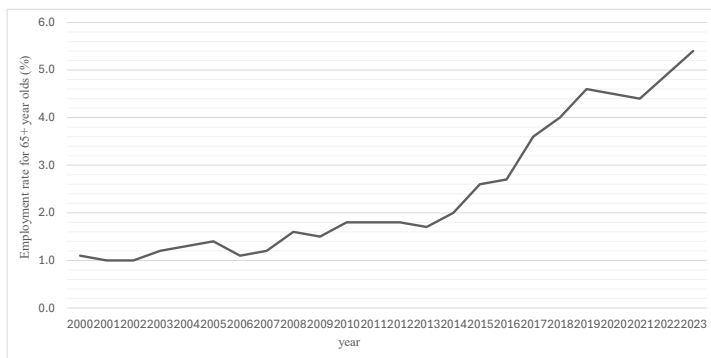


Figure 1.13: Employment rate for people aged 65+ in Slovakia
Source: the author according to ILO [2024]

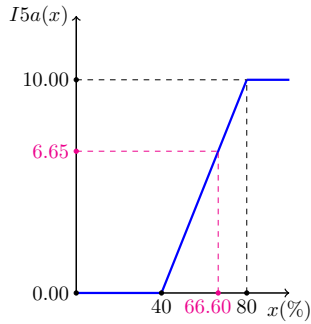


Figure 1.14: Indicator value I5a for 2023
Source: the author according to Mercer [2023]

Table 1.12: Indicator I5b values for the years under review

year	2020	2021	2022	2023
employment rate for aged 65+ years (%)	4.50	4.40	4.90	5.40
I5b indicator value	1.50	1.47	1.63	1.80

Source: the author according to Mercer [2023] and OECD [2024b]

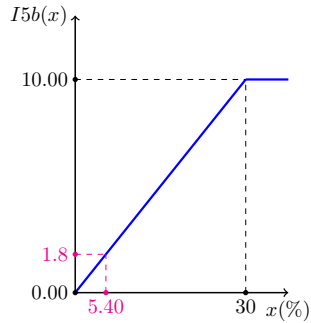


Figure 1.15: Indicator value I5b for 2023
Source: the author according to Mercer [2023]

1.6 Indicator I6 – Government debt and public pension costs

Government debt in Slovakia serves as a crucial economic indicator with a direct impact on public finances and the national budget. As the population ages and pension expenses increase, the sustainability of public finances is becoming an increasingly urgent concern. Pension expenditures make up a substantial portion of Slovakia's public spending, and the majority of pensions are currently funded through a pay-as-you-go system, where working individuals contribute to the Social Insurance Institution, which in turn pays benefits to current pensioners.

Given demographic changes and the projected increase in life expectancy, pension costs are expected to rise in the coming years. This rise in costs may put pressure on government debt, as the government will have to look for ways to finance the pension system without incurring excessive debt.

To maintain the stability of the pension system, it is necessary to consider reforms such as increasing the retirement age, adjusting contribution rates, or modifying the eligibility criteria for pension benefits. Additionally, the government must address the challenge of optimizing public expenditures in other sectors to accommodate the growing pension costs. Implementing pension reforms alongside efficient public financial management will be essential to securing the long-term sustainability of both government debt and the pension system in Slovakia.

The key questions for setting indicator I6 are:

I6a What is the level of adjusted government debt, which is gross government debt less the size of any government investment funds not earmarked for future pension liabilities, expressed as a percentage of GDP?

I6b What is the level of public spending on pensions, expressed as a percentage of GDP, averaged over the latest available data and projected for 2050?

To I6a Based on data from OECD [2024c], SO SR [2024d] and SO SR [2024e] The Statistical Office of the Slovak Republic submitted the Report on the Government Deficit and Debt Level of the Slovak Republic for 2020-2024 to the European Commission by the regular deadline of 1 April 2024. Compared to the October 2023 report, there have been several changes that have been incorporated into the System of National Accounts, which have also affected the data on government debt. The revision was due to updating data on actual taxes and reclassification of units. According to the Statistical Office of the Slovak Republic, these changes did not have a significant impact on government debt. The level of the adjusted government debt as a percentage of GDP for the years under review is recorded in Tables 1.13 and 1.14.

Based on OECD [2024c], debt is defined as "Debt is calculated as the sum of the following categories of liabilities, where appropriate: currency and deposits; debt securities, loans; insurance, pensions and standardised guarantee schemes; and other liabilities."

However, the OECD definition of debt, as given on the OECD website, does not correspond to the definition of the so-called Maastricht debt, which is used in the so-called EDP statistics. This is the so-called Excessive Deficit Procedure (EDP). However, the definition of the Maastricht debt is narrower, i.e., it includes fewer categories than those listed above in the OECD definition. In fact, only the first three types of liabilities from the OECD definition above, i.e., currency and deposits, debt securities and loans, are included in the definition of Maastricht debt. At the same time, for the purposes of Maastricht debt, these categories only include principal, i.e., they do not include interest already accrued but not yet paid.

If only EU countries were to be compared, it would be appropriate to use the commonly used Maastricht debt data. However, our analysis also uses data from Mercer [2023], where OECD data are used by default. To compare Slovakia's sustainability index with other European countries, whose index was determined by Mercer [2023], we also use OECD data for Slovakia. Tables 1.13 and 1.14 present data from both databases for comparison.

Table 1.13: Indicator values I6a for the years under review for Slovakia according to SO SR

year	2020	2021	2022	2023
level of adjusted government debt as % of GDP	58.85	61.09	57.74	56.04
indicator value I6a	6.08	5.93	6.15	6.26

Source: the author according to Mercer [2023] and SO SR [2024e]

Table 1.14: Indicator value I6a for the years under review for Slovakia according to OECD

year	2020	2021	2022	2023
level of adjusted government debt as % of GDP	77.60	78.20	64.00	62.30
indicator value I6a	4.83	7.79	5.73	5.85

Source: the author according to Mercer [2023] and OECD [2024c]

Mercer [2023] for question U6a states that "the maximum score was achieved for countries with zero or negative levels of adjusted government debt, and with a score of zero for countries with adjusted

government debt of 150% of GDP or more." The situation is illustrated in Figure 1.16.

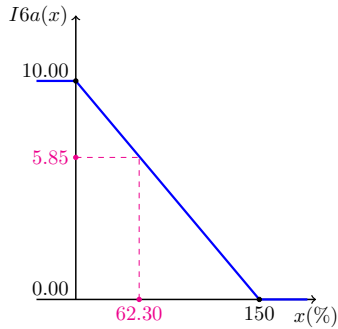


Figure 1.16: Indicator value I6a for 2023 w.r.to OECD [2024c]
Source: the author according to Mercer [2023]

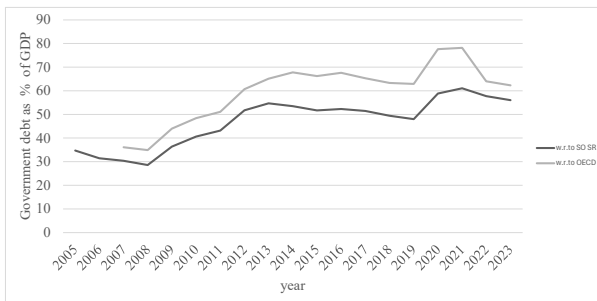


Figure 1.17: Government debt as % of GDP
Source: the author according to SO SR [2024e] and OECD [2024c]

To I6b Pensions at a Glance [2023] reports that the level of public spending on pensions for 2019 is 7.1%, and the projection for 2050 is 13.4% of GDP. The average is, therefore 10.25%. Mercer [2023] reports that

"The maximum score was achieved for schemes with public pension costs of 2% GDP or less, with a score of zero for schemes with costs of 16% of GDP or more." Therefore, when scaling from (16-2)% of GDP to a 10-point scale, we assign a score of 4.11 to indicator I6b - Public pension costs. The graphical dependence of this scale is shown in Figure 1.18.

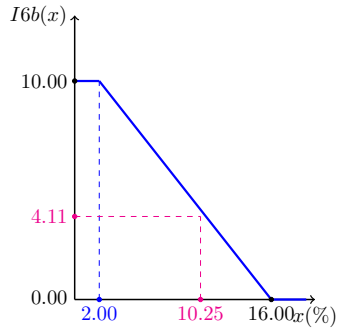


Figure 1.18: Indicator value I6b for 2023
Source: the author according to Mercer [2023], Pensions at a Glance [2023]

1.7 Indicator I7 – Access to part of the savings

The legislative framework for private pension arrangements in Slovakia is regulated by Act No. 43/2004 Coll. on old-age pension savings, which allows older employees to access part of their pension savings. Under this Act, savers who have reached retirement age and continue to work can access their savings in the form of a lump sum or regular benefits.

Employees who opt to work part-time while drawing their pension are entitled to do so, though this choice can influence the amount of their future benefits. By continuing to contribute to their pension fund, they can maintain the advantages linked to their private pension savings, and in some cases, employers may continue to match those contributions.

It is important to note that employees who choose to combine work and pension payments need to be informed of the potential impacts on the level of their pension benefits, including the possibility of a reduction in benefits depending on the level of their income from active employment. In line with the legislation, emphasis is placed on ensuring that employees have sufficient information on the conditions and possibilities of accessing their pension savings, as well as on the possibilities of further saving.

Overall, private pension arrangements provide flexibility for older workers who wish to continue their active working life while at the same time want to secure their pension benefits. These provisions are important for promoting active ageing and ensuring the economic stability of older workers.

The fundamental questions involved in determining the value of I7 are:

I7a Regarding private pension arrangements, can older employees access part of their pension savings or pension and continue to work, e.g. part-time?

I7b If so, can employees continue to contribute and receive benefits at the appropriate rate?

To I7a Older employees can receive a pension and can work in addition to receiving a pension, so we assign a score of 2 to question I7a, and then assign a value of 10 in the Mercer [2023] score. This is true for all surveyed years.

To I7b A pensioner can both work and receive a pension from the first pillar, but can still have his/her funds appreciated in the second and third pillars. This means that we assign a maximum score of 2 to indicator I7b and assign a score of 10 in all years under consideration.

1.8 Indicator I8 – Real economic growth

Slovakia's economic growth rate has varied significantly over the past four years, shaped by global economic trends and the effects of the COVID-19 pandemic. The economy contracted in 2020 and 2021 but began to rebound from 2022, with GDP showing consistent growth. Between 2019 and 2022, the average GDP growth is estimated to be approximately (2-3)%, driven by recovering domestic consumption and export activity.

The projected growth rate for the next three years is more optimistic, with the government projecting that the economy could grow by (3-4)% per year. This projected growth will depend on a number of factors, including continued recovery from the pandemic, investment in innovation and infrastructure, as well as an improvement in the business environment. Slovakia's ability to adapt to global economic challenges, such as rising energy prices, will also be an important consideration.

The government is seeking to implement reforms to encourage entrepreneurship and investment, which should contribute to stable growth. The service sector, as well as the industry, is expected to play a key role in the recovery and the long-term growth trend. Maintaining a favourable economic environment and fostering innovation will be essential to achieve the projected growth in the coming years. Although the projected economic growth rates for the coming years are optimistic, there are a number of critical aspects that may affect their achievement. The first concern is the potential global economic turbulence that could undermine the projected growth. Inflation and rising energy prices may reduce households' purchasing power and thus constrain internal consumption, which is key to economic growth.

In addition, investment in innovation and infrastructure, which are considered essential for sustainable growth, may face administrative obstacles and insufficient funding. There is also a risk that the government will not be able to effectively implement planned reforms and stimulate the business environment, which could lead to stagnation.

Moreover, a lack of focus on green and sustainable practices may have long-term negative consequences for the Slovak economy, especially in relation to climate change and international commitments. Also, youth unemployment and the migration of talented people abroad are problems that may limit the country's economic potential. Overall, there is a need to realistically assess the obstacles that stand in the way of planned growth in order to ensure the long-term stability of the Slovak economy.

The key question for determining the value of indicator I8 is:

- What is the actual rate of economic growth on average over the last four years and projected for the next three years?

The real economic growth rate shows the rate of change in a country's GDP. The real GDP growth rate is a more useful measure than the nominal

GDP growth rate because it takes into account the impact of inflation on economic data. The individual values of the real economic growth rate are shown in Tables 1.15 and 1.16. Please note that these figures are revised and updated very frequently. The figures in both tables are quoted as of 29 November 2024.

Table 1.15: Indicator value I8 for years 2017-2021

year	2017	2018	2019	2020	2021
growth rate GDP (%)	2.90	4.00	2.50	-3.30	4.80
average GDP					
growth rate (%)				1.97	1.86
indicator value I8				4.95	4.76

Source: the author according to Mercer [2023], SO SR [2024e] and IMF [2024]

Table 1.16: Indicator value I8 for 2022-2026

year	2022	2023	2024	2025	2026
growth rate GDP (%)					
and its prediction	1.0	0.8	2.1	2.6	2.8
average growth					
rate GDP (%)	1.66	1.70			
indicator value I8	4.43	4.50			

Source: the author according to Mercer [2023], SO SR [2024e] and IMF [2024]

The average economic growth rate for 2023, that is, the average GDP growth rate over seven years, for 2020-2023 and the forecast for 2024-2026, according to IMF [2024] is at 1.70%. On a scale of (-1.0 - 5.0)% to 10-point scale, the I8 indicator, Real Economic Growth for 2023, is at a score of 4.50.

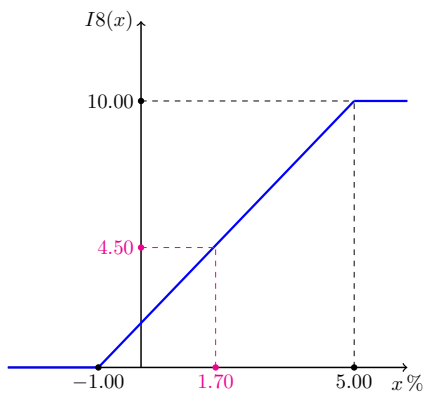


Figure 1.19: Indicator value I8 for 2023

Source: the author according to Mercer [2023] and IMF [2024]

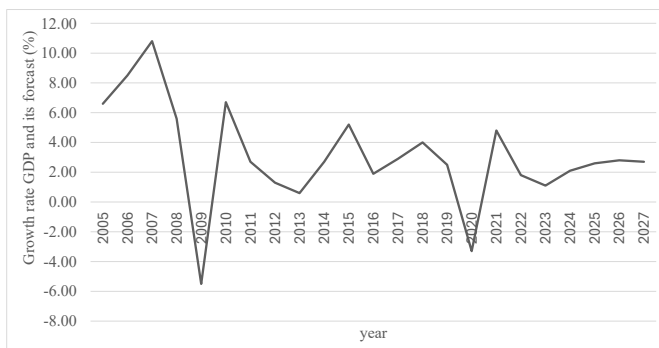


Figure 1.20: Growth rate GDP and its forecast

Source: the author according to SO SR [2024e] and IMF [2024]

1.9 Indicator I9 – Environmental, social and governance (ESG) issues

Directive (EU) 2016/2341 of the European Parliament and of the Council of 14 December 2016 focuses on the activities and supervision of institutions for occupational retirement provision, aiming to strengthen transparency and the protection of pension scheme members, Directive EU [2021]. One of the key aspects of this Directive is the requirement for Member States to ensure that pension funds disclose information on environmental, social and governance (ESG) management factors that influence their investment decisions. The acronym ESG stands for Environmental, Social and Governance, i.e. environmental protection, socially responsible behaviour, ethical and transparent corporate governance.

The purpose of these measures is to encourage responsible investment and ensure that occupational pension institutions consider long-term risks and returns in asset management. The Directive also requires Member States to develop and implement supervisory mechanisms to ensure compliance with these rules. The Directive emphasises the importance of governance and risk management, which contributes to the stability of the overall pension system.

The Directive makes it mandatory for occupational pension institutions to develop policies and strategies that take ESG factors into account when making investments. This increases the confidence of pension scheme members that their savings are managed responsibly and sustainably. Last but not least, the Directive promotes mutual cooperation between Member States to ensure a level playing field in the occupational pensions market across the European Union.

The basic question for determining the value of this indicator is:

- Is it a requirement for pension plan trustees to consider environmental, social and governance (ESG) issues when developing their investment policies or strategies?

Under the Directive, Member States should require occupational pension institutions to disclose information on whether environmental, social and governance (ESG) factors are taken into account in investment decisions and how they form part of their risk management system, Directive EU [2021]. European Union countries had until 13 January 2019 to transpose these new rules into their national laws, Directive EU [2021]. Therefore, we award 2 points for indicator I9, i.e., a maximum score of 10 points.

Chapter 2

DETERMINATION OF INDICATORS WEIGHTS

The weighting of criteria or indicators is crucial in decision-making processes where priorities need to be set. Several methods are used for this purpose, one of the best known being the Saaty exact method developed by Thomas Saaty, Saaty [1977], Saaty [2005]. This method uses pairwise comparisons of criteria or indicators using a 9-point scale, which allows accurate weighting based on the calculation of the so-called eigenvector of the pairwise comparison matrix.

There are also approximate versions of this method that reduce the computational complexity, for example by using averages instead of complex calculations. In our determination of weights in the approximate method, we use the geometric mean.

The following method to be applied is the so-called Thurstone method, which was developed by the psychologist L.L.Thurstone [1927]. This method is mainly used in psychometrics to assess attitudes and preferences. Of course, it can also be used in other cases, e.g. as in our determination of the weights of the observed variables. It has the advantage that it always compares only two criteria or indicators with each other, and thus the decision maker can more easily decide which one criterion or one indicator is more important than the other.

Another modern method is the Best-Worst Method (BWM) by Jafar Rezaei, Rezaei [2015, 2016a,b, 2020], which requires the decision maker to select the best and worst criterion or indicator and determine their relationships with the other criteria or indicators, which is very suitable for large sets of criteria or indicators.

Each of these methods offers a different approach to preference elicitation, and the choice of the appropriate one depends on the requirements of the

decision problem, be it accuracy, simplicity, or the degree of involvement of subjective judgment.

2.1 Weight determination methods

While Mercer includes weights for each indicator in its annual reports, it does not disclose the methodology used to derive them. In our study, we examine the significance of individual indicators through various weighting techniques within the field of multicriteria decision-making, specifically those classified as subjective methods. The methods employed in our research include the aforementioned exact and approximate Saaty's methods, the Thurstone pairwise comparison method, and the Best-Worst method.

In pursuit of an accurate assessment of each indicator's importance, we relied on our expert knowledge and detailed research to subjectively rank them as follows.

We consider the most important indicator to be I1, which reflects the participation rate of the working population in private pension schemes. In our view, private savings play and will play a crucial role in providing greater financial security during retirement. Closely related to this is the I2 indicator, which represents a form of national wealth. In third place, we have included indicator I8, which reflects economic growth over the period and predicts future growth. Next in order of importance is indicator I6, which relates to government debt and public expenditure as well as their predicted future development. Following this, we have placed indicator I4 in fifth place because it highlights the amount of compulsory contributions deferred for retirement. While indicator I3 - life expectancy - is undoubtedly important in determining pension payments, we assume that the rate of growth in life expectancy will not be that extreme. Thus, we have placed the I3 indicator in sixth place. In our view, it is life expectancy that is closely related to indicator I5, which measures labor force participation of the elderly. We ranked indicator I9 last, as we believe that although ESG issues may be a popular topic of discussion at the moment, they do not yet have a tangible impact on the sustainability of pension systems.

This section presents the data set used as the basis for determining the weights of the indicators. Since none of the methods for determining the weights is a priori superior and none can be preferred, it is still up to the decision maker which weights to lean towards, Boda et al. [2021].

2.2 Exact Saaty's method

Saaty [1977] emphasizes that the human mind is capable of meaningfully comparing approximately 7 ± 2 indicators. The sustainability index has exactly 9 indicators, and therefore we can fully use Table 2.1 on page 34.

The first step of the Saaty's method is to construct a matrix that has as many rows and columns as there are indicators. We write the values from 1 to 9 in the table to express the relative importance of the row indicator compared to column one. To make the data consistent, it is obvious that we express the relative "unimportance" as the inverted value. To verify the validity of the matrix, it is first necessary to calculate the so-called Saaty Consistency Index (CI^S)

$$CI^S = \frac{\lambda_{\max} - n}{n - 1}, \quad (2.1)$$

where

- λ_{\max} - the largest positive eigenvalue of the matrix,
- n - number of indicators.

The so-called consistency ratio CR^S is calculated according to the formula

$$CR^S = \frac{CI^S}{RI}, \quad (2.2)$$

where

- RI - Random Index, which is in the Appendix to this monograph on page 78, but also e.g. in Mu et al. [2017]. This value is obtained from a large number of random matrices of a given order n , whose elements are formed by numbers from $1, 2, \dots, 9, \frac{1}{2}, \dots, \frac{1}{9}$.

Remark 2.1. In the notation of the consistency index and also in the consistency ratio, we use the superscript S to specifically indicate that we are working with the Saaty matrix and to distinguish also the indices that we use later in the Best-Worst method. Standardly in the literature, these ratios are reported without these superscripts.

For the matrix to be valid, in other words, for us to consider the matrix as sufficiently consistent, with respect to Mu et al. [2017] the value of CR^S must not exceed 0.10. Therefore, if the consistency ratio is at most 0.10, the matrix can be considered sufficiently consistent, otherwise it is necessary to re-evaluate the mutual comparisons of criteria, or indicators. This statement implies that the consistency index actually expresses the degree of inconsistency of the matrix.

Remark 2.2. In practice, it is rarely possible to achieve full matrix consistency. But it should not be enforced at all costs. In the case of inconsistent matrices, an eigenvector with positive components is searched for, the sum of which is 1, corresponding to the largest eigenvalue λ_{\max} of the matrix. It is appropriate that $\lambda_{\max} \approx n$ and the other eigenvalues are positive and close to 0. This follows from the consideration that small changes in the matrix elements lead to only small changes in the eigenvalues.

Table 2.1: Saaty's scale of relative importance

scale	importance of alternative <i>i</i> before <i>j</i>	inverted value of alternative <i>i</i> before <i>j</i>
Extremely important	9	1/9
Between extremely and very strong importance	8	1/8
Very strong importance	7	1/7
Between strong and very strong importance	6	1/6
Strong importance	5	1/5
Between strong and medium importance	4	1/4
Medium importance	3	1/3
Between medium and equal importance	2	1/2
Equal importance	1	1

Source: the author according to Saaty [2005]

When determining the weights, we proceed from the condition that the elements of the matrix s_{ij} differ as little as possible from the matrix $(\frac{v_i}{v_j})$ and as a suitable measure we use the sum of the squares of the deviations of the elements of both matrices. Therefore, the individual weights, which are listed in Table 2.2, can be calculated using the solver function in MS Office Excel, where the Saaty optimization criterion is minimized

$$\min \xi = \xi^* \quad (2.3)$$

under the conditions

$$\min \sum_{i=1}^n \sum_{j=1}^n \left(s_{ij} - \frac{v_i}{v_j} \right)^2 < \xi \quad (2.4)$$

and

$$v_1, v_2, \dots, v_n > 0 \wedge \sum_{i=1}^n v_i = 1, \quad (2.5)$$

where

- s_{ij} are the individual elements of the matrix, $i, j = 1, 2, \dots, n$,
- v_i - is the weight of the i -th indicator,
- v_j - is the weight of the j -th indicator.

Table 2.2: Exact Saaty's method

i, j	I1	I2	I8	I6	I4	I3	I5	I7	I9	v_i
I1	1	2	3	4	5	6	7	8	9	0.25
I2	$\frac{1}{2}$	1	2	3	4	5	6	7	8	0.22
I8	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	6	7	0.18
I6	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	6	0.13
I4	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	0.08
I3	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	0.05
I5	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	0.04
I7	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	0.03
I9	$\frac{1}{9}$	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	0.02
v_j	0.25	0.22	0.18	0.13	0.08	0.05	0.04	0.03	0.02	1.00

Source: the author

For our research, we use the full range of values from 1 to 9 to determine the weights as accurately as possible. Since we have the indicators listed from most important to least important, we can simply write down the Saaty relative importance of our indicators, as shown in Table 2.2.

In our case, the Saaty's optimization function (2.3) takes the value $\xi^* = 37.3645$. The maximum positive eigenvalue of the matrix, which is also close to our number of indicators, is $\lambda_{\max} = 9.4015042$ and the consistency index according to (2.1) is $CI^S = 0.050188$ and the consistency ratio (2.2) with a random index $RI = 1.45$ is at the level of $CR^S = 0.0346$, Brunner [2008], Dijkstra [2021]. This means that our data can be considered consistent and the corresponding weights relevant.

The weights determined by the exact Saaty's method given in Table 2.2 are used in Chapter 3 on pages 42 and 45.

Remark 2.3. For a more detailed understanding of the relationship between the value of the matrix eigenvalue and the number of observed indicators, see the Appendix on page 77.

Other values of the random index RI can be found in Dijkstra [2021], but also in the Appendix on page 78.

2.3 Approximate Saaty's method

If we do not have a solver function available, we can also use the so-called approximate Saaty method. The approximate determination of the weights was derived from the logarithmic least squares method and the resulting values do not differ much from the weights obtained by more precise procedures, Boda et al. [2021]. In the approximate Saaty method, the average multiple importance is determined for each criterion or indicator using the geometric mean.

Table 2.3: Approximate Saaty's method

i, j	I1	I2	I8	I6	I4	I3	I5	I7	I9	p_i	v_i
I1	1	2	3	4	5	6	7	8	9	4.1472	0.31
I2	$\frac{1}{2}$	1	2	3	4	5	6	7	8	3.0080	0.22
I8	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	6	7	2.1131	0.16
I6	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	6	1.4592	0.11
I4	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	5	1.0000	0.07
I3	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	4	0.6853	0.05
I5	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	0.4732	0.04
I7	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	0.3324	0.02
I9	$\frac{1}{9}$	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	0.2411	0.02
sum										13.4596	1.00

Source: the author

The individual values of p_i are determined according to the formula

$$p_i = \sqrt[n]{\prod_{j=1}^n s_{ij}}. \quad (2.6)$$

From the values of p_i , the normalized weights are usually determined according to the formula

$$v_i = \frac{p_i}{\sum_{i=1}^n p_i}. \quad (2.7)$$

The weights determined by the approximate Saaty method from Table 2.3 are used in Chapter 3 on pages 43 and 47.

2.4 Thurstone method of paired comparison

Thurston's Pairwise Comparison Method was introduced by Louis Leon Thurstone in 1927. This method assumes that it is possible to evaluate the mutual importance of indicators in pairs. The decision maker always compares pairs of indicators and decides which is more important. He then records his choice of pairwise preferences in a table using the following three options:

1. assigns the value $s_{ij} = 1$ if the i -th, i.e. row indicator is more significant than the j -th, i.e., column indicator.
2. assigns the value $s_{ij} = 0$ if the j -th, i.e. column indicator is more significant than the i -th, i.e., row indicator.
3. assigns the value $s_{ij} = 0.5$ if the i -th, i.e. row indicator and the j -th, i.e. column indicator are equally significant, Boda et al. [2021].

Table 2.4: Thurstone method of paired comparison

i, j	I1	I2	I8	I6	I4	I3	I5	I7	I9	w_i	w_i^*	v_i
I1		1	1	1	1	1	1	1	1	8	9	0.20
I2	0		1	1	1	1	1	1	1	7	8	0.18
I8	0	0		1	1	1	1	1	1	6	7	0.16
I6	0	0	0		1	1	1	1	1	5	6	0.13
I4	0	0	0	0		1	1	1	1	4	5	0.11
I3	0	0	0	0	0		1	1	1	3	4	0.09
I5	0	0	0	0	0	0		1	1	2	3	0.07
I7	0	0	0	0	0	0	0		1	1	2	0.04
I9	0	0	0	0	0	0	0	0		0	1	0.02
sum											45.00	1.00

Source: the author

After obtaining the comparison matrix, the number of assigned preferences of pairs is added up row by row, and thus the number of preferences $w_i = \sum_j s_{ij}$ for the i -th indicator. Subsequently, it is possible to determine the weight of the i -th indicator according to the formula

$$v_i = \frac{w_i}{\sum_{i=1}^n w_i}. \quad (2.8)$$

If some value w_i is equal to 0, as in our case for indicator U9, we can add, for example, to each value w_i the value 1. Then we can calculate non-zero normalized weights of individual indicators, which replace the values w_i with the values w_i^* .

The weights determined by this method, which are listed in Table 2.4, are further used in Chapter 3 on pages 44 and 47.

2.5 Best-Worst method

The Best-Worst method is based on a sequential comparison of pairs of criteria, or indicators. It was developed by Jafar Rezaei [2016a]. This method can provide reliable weights in a shorter time. In addition, it is shown that over the course of several years this method has become very popular in multi-criteria decision-making due to its properties, Brunelli et al. [2019], Mi et al. [2019].

The method is implemented in several steps:

1. A set of decision criteria, or indicators, is determined.

2. The best and worst criterion, or indicator, is determined. If more than one criterion, or indicator, is considered the best or worst, one can be arbitrarily chosen, Rezaei [2015].

In our case, among the 9 indicators, the most significant one is identified - Best and the least significant - Worst. The best in our particular case is indicator I1 and the worst is I9.

3. The preference of the best indicator will be gradually expressed in comparison with the other indicators using the cardinal scale, which was also used in previous methods. The value 1 again represents a match in importance. Thus, we get $A_B = (s_{B1}, \dots, s_{Bn})$ as the vector of the best indicator relative to the others. In our case, it is the vector $A_B = (1, 2, 3, 4, 5, 6, 7, 8, 9)$, Table 2.5.
4. The preference of other indicators to the worst indicator is gradually expressed by the vector $A_W = (s_{1W}, \dots, s_{nW})^T$. This vector in the framework of our indicators is $A_W = (9, 8, 7, 6, 5, 4, 3, 2, 1)^T$ and is written in Table 2.5.

Table 2.5: Best-Worst method

Indicator		I1	I2	I8	I6	I4	I3	I5	I7	I9
Selected the best		I1								
Selected the worst		I9								
The best to others	A_B	1	2	3	4	5	6	7	8	9
The worst to others	A_W									
I1		9								
I2		8								
I8		7								
I6		6								
I4		5								
I3		4								
I5		3								
I7		2								
I9		1								
optimal weights v_i^*		0.31	0.19	0.06	0.08	0.05	0.10	0.05	0.13	0.03

Source: the author according to Rezaei [2016a]

5. Determination of the optimal weights $(v_1^*, v_2^*, \dots, v_n^*)$.

Optimal weights are determined using a mini-max optimization model

$$\min \sup \left\{ \left| \frac{v_B}{v_i} - s_{Bj} \right|, \left| \frac{v_i}{v_W} - s_{iW} \right| \right\} \quad (2.9)$$

with conditions $\sum_{i=1}^n v_i = 1$ and $v_1, v_2, \dots, v_n > 0$.

This model is converted to the following model

$$\min \xi = \xi^* \quad (2.10)$$

under conditions

$$\left| \frac{v_B}{v_i} - s_{Bj} \right| \leq \xi \quad (2.11)$$

$$\left| \frac{v_i}{v_W} - s_{iW} \right| \leq \xi \quad (2.12)$$

and $\sum_{i=1}^n v_i = 1$ and $v_1, v_2, \dots, v_n > 0$. By solving this model we obtain the optimal weights $(v_1^*, v_2^*, \dots, v_n^*)$.

6. The last step is to calculate the level of inconsistency using a robust index called the consistency ratio CR^{BW} , which is given by

$$CR^{BW} = \frac{\xi^*}{CI^{BW}}, \quad (2.13)$$

where CI^{BW} - the consistency index, which is for the number of indicators and at the same time for the maximum value of the relative importance scale in the pairwise comparison of indicators $n = s_{BW} = 9$ at the level of 5.23, Rezaei [2015].

Using the solver Rezaei [2016b], we obtained the optimal value $\xi^* = 0.0684$, and therefore $CR^{BW} = 0.0131$. The consistency ratio is a number from the interval $[0, 1]$ and the smaller it is, the more reliable the results are.

Remark 2.4. The values of the consistency index for the Best-Worst method for different numbers of indicators can be found in the Appendix on page 78.

Chapter 3

SUSTAINABILITY INDEX VALUE

The aim of this monograph is to assess the sustainability index of the Slovak pension system and to compare it with the sustainability indices of selected European countries. This objective holds significance not only in academic discourse but also in practical application, as the pension system constitutes a fundamental component of every country's social policy. Like many other nations, Slovakia is confronted with the challenges posed by an ageing population and the growing financial demands on its pension system. The analysis of the sustainability index makes it possible to assess to what extent the current system is able to cope with these challenges in the long term. Moreover, comparison with selected European countries provides a broader context and helps to identify possible examples of good practice or areas for improvement. The objective is not only to present the current situation but also to outline potential future developments. Accordingly, this paper seeks to contribute to the ongoing discourse on pension system sustainability, both within Slovakia and across the wider European landscape.

3.1 Weighted score of indicators

The scores for each indicator are taken from Mercer [2023]. Some indicators sometimes have two or more questions and their answers are in some cases assigned different weights. These questions are labelled with the letters a, b, or a, b, c, d, according to their number in the indicators. The indicators are scored on a scale of 0 to 10, some from 0 to 2. Those indicators that are scored on a scale of 0 to 10 are listed in the Tables 3.1 - 3.5 as 10. Those that are rated on a score scale of 0 to 2 are finally converted to a scale of 0 to 10 and tabulated as 10(2).

The values of the sustainability index of the pension systems of selected European countries for 2023 are determined on the basis of the individual scores and weights set out in Chapter 2. The maximum values of the scores according to Mercer [2023] are written in the Table 3.1. Some indicators have been divided by Mercer [2023] into 2 to 4 questions and each question has been assigned a score of 10 points, so for the overall sustainability index we consider a total score of 150 points. For indicators I7 and I9, the number 2 is given in brackets, which means that the answer base is 0, 1 or 2 and then the value is recalculated in direct proportion to the value of 10 as shown in the sub-sections 1.7 and 1.9.

Table 3.1: Maximum values of the sustainability index indicator scores based on the weights determined by Mercer [2023]

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	10	10	10	10	10	10	10(2)	10	10(2)
b			10		10	10	10(2)		
c			10						
d			10						
total score = 150									
Mercer [2023] - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.20	0.15	0.05	0.10	0.08	0.05	0.04	0.08	0.02
b			0.05		0.02	0.05	0.01		
c			0.05						
d			0.05						
x_i	2.00	1.50	2.00	1.00	1.00	1.00	0.50	0.80	0.20
maximal value of the index = $10 \times \sum_{i=1}^9 x_i = 100$									

Source: the author according to Mercer [2023].

Table 3.2: Maximum values of the sustainability index indicator scores based on weights determined by the exact Saaty's method

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	10	10	10	10	10	10	10(2)	10	10(2)
b			10		10	10	10(2)		
c			10						
d			10						
total score = 150									
exact Saaty's metod - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.25	0.22	0.0125	0.08	0.02	0.065	0.015	0.18	0.02
b			0.0125		0.02	0.065	0.015		
c			0.0125						
d			0.0125						
x_i	2.50	2.20	0.50	0.80	0.40	1.30	0.30	1.80	0.20
maximal value of the index = $10 \times \sum_{i=1}^9 x_i = 100$									

Source: the author

Table 3.3: Maximum values of the sustainability index indicator scores based on weights determined by the approximate Saaty's method

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	10	10	10	10	10	10	10(2)	10	10(2)
b			10		10	10	10(2)		
c			10						
d			10						
total score = 150									
approximate Saaty's method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.31	0.22	0.0125	0.07	0.02	0.055	0.01	0.16	0.02
b			0.0125		0.02	0.055	0.01		
c			0.0125						
d			0.0125						
x_i	3.10	2.20	0.50	0.70	0.40	1.10	0.20	1.60	0.20
maximal value of the index = $10 \times \sum_{i=1}^9 x_i = 100$									

Source: the author

Table 3.4: Maximum values of the sustainability index indicator scores based on weights determined by the Thurstone method of paired comparison

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	10	10	10	10	10	10	10(2)	10	10(2)
b			10		10	10	10(2)		
c			10						
d			10						
total score = 150									
Thurstone method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.20	0.18	0.0225	0.11	0.035	0.065	0.02	0.16	0.02
b			0.0225		0.035	0.065	0.02		
c			0.0225						
d			0.0225						
x_i	2.00	1.80	0.90	1.10	0.70	1.30	0.40	1.60	0.20
maximal value of the index = $10 \times \sum_{i=1}^9 x_i = 100$									

Source: the author

Table 3.5: Maximum values of the sustainability index indicator scores based on weights determined by the Best-Worst method

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	10	10	10	10	10	10	10(2)	10	10(2)
b			10		10	10	10(2)		
c			10						
d			10						
total score = 150									
Best-Worst method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.31	0.19	0.015	0.08	0.025	0.05	0.025	0.13	0.03
b			0.015		0.025	0.05	0.025		
c			0.015						
d			0.015						
x_i	3.10	1.90	0.60	0.80	0.50	1.00	0.50	1.30	0.30
maximal value of the index = $10 \times \sum_{i=1}^9 x_i = 100$									

Source: the author

3.2 Sustainability pension index of Slovakia

As Slovakia was not included in the group of countries for which Mercer determines the overall pension index, we determined the individual score for Slovakia separately. The remaining scores for selected European countries were obtained from Mercer [2023]. Our aim was to determine the weights of the sustainability indicators using the selected methods and compare them with Mercer's approach, and at the same time to determine the position of Slovakia among these countries.

In the context of determining the weights, it is essential to emphasise that the choice of method can significantly influence the resulting view of the importance of individual indicators. While Mercer does not indicate how it specifically determined the weights, we have chosen to use methods that allow for flexibility and adaptation to the specific requirements of the sustainability index. The Saaty's method we have implemented is based on a range of comparative criteria or indicators and allows us to rank indicators with respect to their relative importance, which is useful when working with fewer criteria or indicators. Similarly, Thurston's method of pairwise comparison offers an effective tool as it allows us to analyse the interrelationships between criteria or indicators.

The Best-Worst method, which is one of the newer weighting techniques, allows us to determine the most and least important indicators and then calculate the weights of the other indicators based on these benchmarks. Given that the calculation of weights using different methods may give different results, it is important to analyse how each method contributes to the final assessment.

Examining these approaches allows us to understand to what extent the weights assigned to each indicator depend on the method used and to what extent the results may be conditioned by the subjective preferences of the decision maker. At the same time, we are aware that each of these methods has its strengths and weaknesses. For example, Saaty's method may be challenging to accurately compare a larger number of criteria or indicators, whereas Thurston's method is less accurate in situations where some indicators are not clearly comparable.

In implementing the Best-Worst method, we emphasized the identification of indicators that we consider key in the sustainability index, thereby highlighting indicators that have a more significant impact on the sustainability assessment. This method helped us to identify not only the most significant indicators but also those that are less significant. Overall, it is clear that the different methods bring different perspectives to the issue of indicator weights and help us to gain a holistic view of their importance within the decision-making process. We can confirm that our view of the importance of sustainability indicators is in close alignment with Mercer's view.

Table 3.6: The score values of the sustainability index indicators and its total value based on weights determined by the exact Saaty's method

<i>i</i>	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	5.52	1.06	8.44	4.58	6.65	5.85	10	4.50	10
b			6.40		1.80	4.11	10		
c			4.28						
d			4.00						
exact Saaty's method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.25	0.22	0.0125	0.08	0.02	0.065	0.015	0.18	0.02
b			0.0125		0.02	0.065	0.015		
c			0.0125						
d			0.0125						
x_i	1.3800	0.2332	0.2890	0.3664	0.1690	0.6474	0.3000	0.8100	0.2000
value of the index = $10 \times \sum_{i=1}^9 x_i = 43.95$									

Source: the author

Table 3.7: The score values of the sustainability index indicators and its total value based on weights determined by the approximate Saaty's method

<i>i</i>	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	5.52	1.06	8.44	4.58	6.65	5.85	10	4.50	10
b			6.40		1.80	4.11	10		
c			4.28						
d			4.00						
Approximate Saaty's method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.31	0.22	0.0125	0.07	0.02	0.055	0.01	0.16	0.02
b			0.0125		0.02	0.055	0.01		
c			0.0125						
d			0.0125						
x_i	1.7112	0.2332	0.2890	0.3206	0.1690	0.5478	0.2000	0.7200	0.2000
value of the index = $10 \times \sum_{i=1}^9 x_i = 43.91$									

Source: the author

Table 3.8: The score values of the sustainability index indicators and their total value based on weights determined by the Thurstone method

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	5.52	1.06	8.44	4.58	6.65	5.85	10	4.50	10
b			6.40		1.80	4.11	10		
c			4.28						
d			4.00						
Thurstone method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.20	0.18	0.0225	0.11	0.035	0.065	0.02	0.16	0.02
b			0.0225		0.035	0.065	0.02		
c			0.0225						
d			0.0225						
x_i	1.1040	0.1908	0.5202	0.5038	0.2958	0.6474	0.4000	0.7200	0.2000
value of the index= $10 \times \sum_{i=1}^9 x_i = 45.82$									

Source: the author

Table 3.9: The score values of the sustainability index indicators and its total value based on weights determined by the Best-Worst method

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
a	5.52	1.06	8.44	4.58	6.65	5.85	10	4.50	10
b			6.40		1.80	4.11	10		
c			4.28						
d			4.00						
Best-Worst method - normed weights $w_i, \sum_{i=1}^9 w_i = 1$									
a	0.31	0.19	0.015	0.08	0.025	0.05	0.025	0.13	0.03
b			0.015		0.025	0.05	0.025		
c			0.015						
d			0.015						
x_i	1.7112	0.2014	0.3468	0.3664	0.2113	0.4980	0.5000	0.5850	0.3000
value of the index= $10 \times \sum_{i=1}^9 x_i = 47.20$									

Source: the author

3.3 Sustainability pension index of selected European countries

The analysis also involved referencing international benchmarks to evaluate how Slovakia's indicator scores align with those of other countries. Although Mercer does not supply direct data for Slovakia, our calculated scores enable a reasonably accurate estimation of the country's position within an international sustainability ranking.

Table 3.10 provides an overview of the assessment of the sustainability index of pension systems for different countries based on different methods of determining the weights of the indicators. The maximum index score is 100, with higher values indicating better sustainability of the pension system. The countries in this table are ranked according to the Mercer [2023] score. Specific calculations of the sustainability index according to our weights and the scores determined by Mercer [2023] are shown for Iceland in the Appendix on pages 79 and 80.

At a glance, we see that countries such as Iceland, Denmark and the Netherlands score high on all methods. Iceland scores highest on all methods, with the highest score on the Best-Worst method - 85.40 points, confirming its stable position as a leader in pension system sustainability. Denmark and the Netherlands are in a similar position. Conversely, countries such as Italy and Austria are at the bottom of the ranking, with low scores in all methods, indicating problems with the sustainability of their pension systems. The table shows that Slovakia is only ranked 12th among the countries surveyed.

In the Appendix to this monograph, on page 55, we also present the average monthly salary in the countries studied for a closer analysis of our index. Although countries such as Germany, France, Belgium, Austria as well as Italy are at the bottom of the table with the lowest sustainability index scores, they have a high average monthly net wage and thus the population is able to save for retirement.

Much more could be discussed on this subject, because we see that the relatively "rich" countries such as Germany, France, but also Belgium, are worse off in terms of the sustainability of pension systems. However, these countries have high scores on the completeness and integrity indices, which puts them much higher in Mercer's overall assessment of the pension index. What causes these countries to have low sustainability index scores are predominantly the I4 - Funded Mandatory Contributions and I7 - Access to a Portion of Savings indicators. It is also interesting to note that Slovakia scores most poorly on the sustainability index indicator I2 - Level of pension assets. However, based on Gubalová et al. [2021] we can also say that the index of sustainability of the pension system in Slovakia is the lowest compared to the index of completeness and integrity.

Looking at the different methods, we can see some differences in the results. The exact Saaty's method and the approximate Saaty's method have similar results, with the approximate Saaty's method tending to produce slightly higher scores. This trend is evident for most countries.

Table 3.10: Sustainability index determined using selected methods weighting of indicators, maximum score 100 points

(countries are ranked in descending order of score Mercer [2023])

country	w.r.t. Exact Saaty's method	w.r.t. Approx. Saaty's method	w.r.t. Thurstone method	w.r.t. Best- Worst method	w.r.t. Mercer [2023]	average
1. Iceland	82.97	84.63	82.49	85.40	83.80	83.87
2. Denmark	81.26	83.10	80.62	83.94	82.50	82.23
3. Netherlands	82.25	84.13	78.95	84.85	82.40	82.55
4. Sweden	76.49	78.66	74.53	78.88	75.60	77.14
5. Switzerland	74.59	76.90	72.06	75.94	70.60	74.87
6. Finland	64.98	68.23	62.87	69.82	65.60	66.48
7. G.Britain	59.51	59.74	60.02	61.78	62.70	60.26
8. Norway	57.78	58.69	57.18	59.42	59.10	58.27
9. Croatia	57.96	59.20	56.53	61.04	56.00	58.68
10. Ireland	56.82	55.86	56.04	55.25	54.40	55.99
11. Poland	49.62	52.46	46.96	50.69	45.40	49.93
12. Slovakia	43.95	43.91	45.82	47.20	—	45.22
13. Germany	39.40	40.36	40.51	43.22	45.30	40.87
14. France	41.07	44.03	39.04	46.73	41.80	42.72
15. Belgium	38.83	41.21	37.03	40.73	39.40	39.45
16. Portugal	26.07	23.73	28.94	25.97	32.00	26.80
17. Spain	24.32	23.42	26.05	25.53	28.50	24.83
18. Italy	19.33	19.34	20.78	19.93	23.70	19.85
19. Austria	19.96	19.48	21.07	19.21	22.60	19.93
score range	63.64	65.29	61.71	66.19	61.20	64.02
average score	52.48	53.53	51.97	54.50	53.97	53.12

Source: the author

It is also interesting to compare the results of the Thurstone method with the others. This method tends to produce lower values, with the lowest range of scores in this method - 61.71 points. It produces lower scores for countries that have a Mercer [2023] score higher than 39.40 (Belgium), but paradoxically higher for countries that have lower scores, such as Portugal, Spain, Italy and Austria. This fact could indicate that the Thurstone method has less

variability and less sensitivity to differences between individual countries, which may be due to the nature of this method, which evaluates individual indicators in pairs.

The Best-Worst method yields the largest range of scores of 66.19 points, which could indicate that it is more "optimistic" in its assessment and that when weighting countries generally receive higher scores. This method identifies key and less significant indicators and may therefore be more sensitive to outliers, which would explain the higher values for some countries.

Comparing Slovakia's score with other countries, we see that Slovakia achieves values lower than the average of the table, with an overall average of 45.22 points, which according to Mercer [2023] indicates that the Slovak pension system in the area of sustainability falls into category D on a scale from A to E in the range of points from 35 to 50 points, and therefore has weaknesses and shortcomings that need to be addressed and without improvements its sustainability is questionable. A more detailed breakdown of the categories can be found in Table 3.14 on page 54.

Slovakia achieves the highest score in the Best-Worst method - 47.20 points and the lowest in the approximate Saaty's method - 43.91 points. This difference suggests that the conclusion about the sustainability of the pension system can be significantly influenced by the choice of the assessment method. But it is still clear that Slovakia remains in category D.

It is worth noting that the scores derived from the various methods range from 61.71 to 66.19 points, suggesting that each method places slightly different levels of emphasis on the individual indicators when assigning weights. The value of the range of scores Mercer [2023] is at the level of 61.20 points and is the lowest compared to the values determined by us. The average score for all monitored countries is at the level of 53.12 points. At the same time, we see that more than half of the monitored countries achieve scores at the A to C level. Unfortunately, we have to state that Slovakia is in the worst half of the monitored countries.

In conclusion, we can say that the choice of method has a significant impact on the assessment of the sustainability of pension systems. While some countries achieve high values across all methods, other countries show significant differences.

Table 3.11 shows the absolute differences between the scores determined by individual methods and the values reported by Mercer in 2023. Such differences help us understand how accurately or consistently each method approximates the assessment of the sustainability of the pension system.

The table calculates the sums of absolute differences for each method. The Thurstone method shows the smallest absolute differences - 40.11 points, while the approximate Saaty's method has the largest differences at the level of 60.05 points. This indicates that the Thurstone method is closest to the Mercer index results, while the approximate Saaty's method deviates the most from these values.

The average relative differences show how the results of the individual methods differ in relation to the Mercer values. The Thurstone method shows the lowest sum of relative differences at 0.66 points, which confirms its higher accuracy and consistency with the Mercer index. The approximate Saaty's method has the highest sum of relative differences at 0.98 points, which indicates a larger deviation compared to the Mercer index values.

Table 3.11: Absolute differences between the scores determined by individual methods and Mercer [2023]

country	w.r.t. Exact Saaty's method	w.r.t. Approx. Saaty's method	w.r.t. Thurstone method	w.r.t. Best- Worst method	Mercer [2023]	average
Iceland	0.83	0.83	1.31	0.60	0.00	0.07
Denmark	1.24	0.60	1.88	1.44	0.00	0.27
Netherlands	0.15	1.73	3.45	2.45	0.00	0.15
Sweden	0.89	3.06	1.07	3.28	0.00	1.54
Switzerland	3.99	6.30	1.46	5.34	0.00	4.27
Finland	0.62	2.63	2.73	4.22	0.00	0.88
G.Britain	3.19	2.96	2.68	0.92	0.00	2.44
Norway	1.32	0.41	1.92	0.32	0.00	0.83
Croatia	1.96	3.20	0.53	5.04	0.00	2.68
Ireland	2.42	1.46	1.64	0.85	0.00	1.59
Poland	4.22	7.06	1.56	5.29	0.00	4.53
Germany	5.90	4.94	4.79	2.08	0.00	4.43
France	0.73	2.23	2.76	4.93	0.00	0.92
Belgium	0.57	1.81	2.37	1.33	0.00	0.05
Portugal	5.93	8.27	3.06	6.03	0.00	5.82
Spain	4.18	5.08	2.45	2.97	0.00	3.67
Italy	4.37	4.36	2.92	3.77	0.00	3.85
Austria	2.64	3.12	1.53	3.39	0.00	2.67
sum of absolute differences	45.15	60.05	40.11	55.25	0.00	40.66
sum of relative differences	0.74	0.98	0.66	0.90	0.00	0.66

Source: the author

Sum of relative differences SRD is calculated using the formula

$$SRD = \frac{\sum(\text{score of a specific method} - \text{score w.r.t. Mercer [2023]})}{\text{score range w.r.t. Mercer [2023]}} \quad (3.1)$$

The largest absolute differences between the evaluation by individual methods and the Mercer [2023] index are recorded for Portugal, Spain, Italy and Austria, but also Switzerland. For example, Portugal has a difference of

up to 6.03 points for the Best-Worst method, while for the approximate Saaty's method this difference is even higher, up to 8.27 points. Conversely, the countries with the lowest differences in most methods are Iceland, Denmark and Norway, which may indicate that their pension systems are more stable and less sensitive to changes in the weights of individual indicators.

From Table 3.11 we also see that each method has a different impact on the accuracy of the evaluation depending on the country. For example, the Thurstone method has relatively low differences for most countries, but in some cases, such as the Netherlands, Germany and Portugal, it shows higher deviations. On the other hand, the Best-Worst method is more consistent across countries but still shows large differences for countries such as Switzerland, Croatia, Poland and Portugal.

Based on this table, we can say that the choice of method can significantly affect the resulting assessment of the sustainability of pension systems for some countries. While the exact Saaty method appears to be the most accurate compared to the Mercer Sustainability Index, the approximate Saaty's method shows the largest differences.

Table 3.12 provides the ranking of countries according to the Sustainability Index values, which were determined by our methods and the Mercer ratings from 2023. We analyze the differences in the ranking of individual countries under the different methods, which gives us an overview of the stability and consistency of the ratings across different techniques.

Iceland ranks first in three methods, including the Mercer rating, indicating a high stability of its rating regardless of the method used. Denmark also shows a relatively stable ranking, ranking second and third. This indicates a consistently high level of sustainability of the pension system. The same is true for the Netherlands. Sweden, Switzerland, Finland and the United Kingdom which show high stability in their rankings, ranking fourth to seventh in each method. Norway and Croatia share eighth and ninth place. Ireland and Poland show stable positions, although only in tenth and eleventh place. Portugal, Spain, Italy and Austria have stable positions determined by all methods, but their pension systems show high instability.

Spain, Italy and Austria are consistently in the bottom three places across all methods, with Austria always last in the Best-Worst method and the Mercer index. It changes its position with Italy. This trend suggests that these countries' pension systems are likely to have the greatest sustainability challenges, which may be due to structural challenges such as ageing populations or unsustainable system design.

Table 3.12 allows us to see that while there are some differences between methods, the results are generally consistent with the Mercer ranking. This suggests that the Mercer index has consistent foundations that are supported by multiple methodological approaches.

The last column, "Average", shows the average ranking of countries across all methods. Countries with low averages, such as Iceland, Denmark and

Table 3.12: Ranking of individual countries based on the value of the sustainability index determined by individual methods

country	w.r.t. Exact Saaty's method	w.r.t. Approx. Saaty's method	w.r.t. Thurstone method	w.r.t. Best-Worst method
Iceland	1	1	1	1
Denmark	3	3	2	3
Netherlands	2	2	3	2
Sweden	4	4	4	4
Switzerland	5	5	5	5
Finland	6	6	6	6
Great Britain	7	7	7	7
Norway	9	9	8	9
Croatia	8	8	9	8
Ireland	10	10	10	10
Poland	11	11	11	11
Slovakia	12	13	12	12
Germany	14	15	13	14
France	13	12	14	13
Belgium	15	14	15	15
Portugal	16	16	16	16
Spain	17	17	17	17
Italy	19	19	19	18
Austria	18	18	18	19

Source: the author

Table 3.13: Absolute rank difference specific method - Mercer 2023

country	w.r.t. Exact Saaty's method	w.r.t. Approx. Saaty's method	w.r.t. Thurstone method	w.r.t. Best-Worst method
Iceland	0	0	0	0
Denmark	1	1	0	1
Netherlands	1	1	0	1
Sweden	0	0	0	0
Switzerland	0	0	0	0
Finland	0	0	0	0
Great Britain	0	0	0	0
Norway	1	1	0	1
Croatia	1	1	0	1
Ireland	0	0	0	0
Poland	0	0	0	0
Germany	2	3	1	2
France	0	1	1	0
Belgium	1	0	1	1
Portugal	1	1	1	1
Spain	1	1	1	1
Italy	1	1	1	0
Austria	1	1	1	0
sum	8	10	2	6

Source: the author

Sweden, are consistently ranked as the most sustainable, while countries with high averages, such as Austria and Italy, are consistently ranked as the least sustainable.

The table shows that while individual methods may slightly change the ranking of countries in certain cases, in most cases countries are ranked in stable positions. This means that the choice of method may not fundamentally change the overall conclusions on the sustainability of pension systems.

Table 3.13 shows the differences between the rankings in absolute terms with the Mercer ranking benchmark. In the last column of Mercer [2023], the values of 0 are given for all countries, indicating that the Mercer 2023 results are used as the ranking reference. This means that all other methods - exact Saaty's, approximate Saaty's, Thurstone and Best-Worst methods are compared against Mercer 2023.

The Thurstone method shows minimal differences to Mercer. Most countries have a value of 0, which means that the positions coincide. The exact and approximate Saaty's methods show similar results, with slight deviations. Most of the differences are only by 1 position. But Germany shows the largest differences - 2 places according to the exact Saaty's method and 3 places according to the approximate Saaty's method and 2 places according to the Best-Worst method. Other countries, e.g. Denmark, the Netherlands, Norway and Croatia, have small differences mostly by 1 place.

The Exact and Approximate Saaty's methods show very similar results, as the differences between their sums are small - 8 versus 10. Thurstone method has results that are closest to Mercer 2023, making it the most stable of the other methods.

Countries such as Iceland, Sweden, Switzerland, Finland, Great Britain, Ireland and Poland show no difference in ranking against Mercer 2023, regardless of the method used. These countries have stable rankings in all methods.

The stability of the rankings in determining the sustainability of pension systems for a number of countries shows that the differences between the methods of determining the weights of the different indicators are negligible for these countries. Therefore, our results can be considered relevant also for Slovakia and other selected European countries.

3.4 Pension sustainability index score

The score of the overall pension index in Mercer [2023] is determined as the weighted arithmetic average of 3 sub-indices - the adequacy index, the sustainability index and the completeness index. The sustainability index score is taken from Mercer [2023] and partially adjusted for the sustainability index of pension schemes.

Table 3.14: Pension sustainability index score

level	index value	pension scheme description
A	]80 – 100]	first class sustainable pension scheme
B+	]75 – 80]	scheme with many good features but has some areas for improvement that distinguish it from a level A scheme
B	]65 – 75]	
C+	]60 – 65]	system, which has some good features but also has major shortcomings that should be addressed; without these improvements, its long-term sustainability may be questioned
C	]50 – 60]	
D	]35 – 50]	the system has weaknesses and major deficiencies that need to be addressed, without these improvements its sustainability is questionable
E	]0 – 35]	weak to almost no sustainability of the system

Source: the author according to Mercer [2023]

Table 3.15: Pension sustainability index and Net average monthly wages in the countries surveyed in March 2024, Wikipedia [2024]

country	Pension sustainability index	Net average monthly wage (eur)
Iceland	A	3,906
Denmark	A	3,490
Netherlands	A	3,771
Sweden	B+	3,349
Switzerland	B	5,811
Finland	B	2,433
Great Britain	C+	2,631
Norway	C	3,543
Croatia	C	1,366
Ireland	C	3,105
Poland	D	1,455
Slovakia	D	1,130
Germany	D	3,054
France	D	2,659
Belgium	D	2,463
Portugal	E	1,342
Spain	E	1,964
Italy	E	2,017
Austria	E	3,205

Source: the author according to Wikipedia [2024]

CONCLUSION

The sustainability of pension systems mirrors the complexity of the challenges confronting them. It represents a global issue, as demographic and economic shifts—along with their forecasts—pose significant risks to financial stability. As life expectancy rises, pension schemes are increasingly strained by declining fertility rates and a growing proportion of the population reaching retirement age. These trends increase the burden on the economically active population, which finances pensions through contributions. The basic principle of pay-as-you-go is applied in social insurance systems almost all over the world, and this is no different in Slovakia. In this case, it is the so-called "Pay As You Go" system, in which every employed individual contributes to the Social Insurance Institution for the payment of pensions to current pensioners.

A significant measure to enhance the sustainability of pension systems is raising the retirement age, which helps alleviate pressure on public finances. This approach enables individuals to contribute to the system for a longer period while postponing the commencement of pension benefits. The Slovak Society of Actuaries has an important role in this area in Slovakia, which also addresses the issue of sustainability in working groups and proposes solutions. The results of the analysis of one such working group were built into the law amending the Social Insurance Act, Act No. 352/2022 Coll. [2022], by re-establishing that from the year of birth of the insured person in 1967, the increase in pension age will be linked to life expectancy. The legislation on the reduction of the retirement age by six months for each child brought up, up to a maximum of 18 months, is maintained.

Moreover, several countries are exploring the option of raising contributions to pension schemes as a means to support budgetary balance and strengthen financial stability. Another measure is the introduction of multi-pillar pension schemes. This is also the case in Slovakia, where public, employee and individual contributions are combined, thereby spreading the risk of instability of pension systems.

Enhancing private pension insurance represents another approach that empowers individuals to have greater control over their retirement savings. It can serve as a supplement to public pension systems and contribute to

increased financial security on a personal level. An innovative approach is the introduction of 'longevity insurance', which provides an income for people who live longer than expected, reducing the risk of running out of savings in old age. Contributions from renowned authors, such as the Berstein and Morales Sepúlveda [2021] study analysing longevity insurance for defined contribution schemes, provide a deeper insight into how pension stability can be ensured in an environment of rising longevity and low interest rates. Longevity insurance helps reduce the risk of retirees outliving their expected lifespan and also enables higher pension payouts by utilizing savings in the form of 'deferred annuities'. Another important contribution in the field of actuarial modelling is the publication Krčová et al. [2022], where the authors offer modern methods for determining premiums in life insurance. Current research shows that sustainability is becoming a key issue in pension policy and requires continuous attention in both academic and policy circles. The analysis of pension reforms in Europe by Hinrichs [2021] plays a significant role in shaping national policy decisions. Furthermore, actuarial research in pension modelling provides a vital contribution to understanding and assessing the sustainability of pension systems, as highlighted by Krčová et al. [2022], Sakálová and Zelinová [2023], and Špirková et al. [2023].

In some countries, tax incentives are proposed for those who save for retirement individually. Tax incentives can motivate people to save more and thus relieve pressure on public systems. In Slovakia, taxpayer contributions to supplementary pension savings can be made under Act No. 650/2004 Coll. on supplementary pension savings as amended, to supplementary pension savings abroad of the same or comparable type, as well as contributions to a pan-European personal pension product under Act No. 129/2022 Coll. on a pan-European pension product and contributions to a pan-European personal pension product abroad of the same or comparable type, deducted from the tax base in the amount in which they were demonstrably paid in the relevant tax period, up to a maximum of EUR 180 per year in aggregate, Act No. 650/2004 Coll. [2004] and Act No. 129/2022 Coll. [2022].

Reforming health and social care spending for the elderly is also essential, as these costs frequently impose a considerable strain on public finances. Enhancing sustainability involves measures such as encouraging the employment of older individuals and facilitating their reintegration into the workforce.

Adjusting population policies and providing support to families can contribute to alleviating demographic pressures over the long term. Enhancing financial literacy among the population can lead to more informed decision-making regarding pensions and personal savings.

International organisations recommend that countries adapt their pension policies to their specific circumstances. A comprehensive approach involving reforms at multiple levels is essential to sustain pension systems. Reforms should aim at financial stability but also protect the dignity of pensioners.

Another important contribution to the sustainability of pension systems

is the analysis of Karl Hinrichs from the Centre for Inequality and Social Policy in Bremen, who offers a detailed analysis of pension reforms in Europe, Hinrichs [2021]. His work highlights that European countries are responding to population ageing with several reforms that include changes in contribution rates, reductions in benefits, the introduction of multi-pillar schemes and the injection of additional financial resources. Hinrichs' analysis underlines that while these measures promote the long-term sustainability of the schemes, they may increase the risk of poverty in old age, thereby undermining one of the fundamental objectives of pension systems - to provide a decent retirement.

Comparable decision-making challenges emerge when advanced methods are applied to assess policy and economic measures related to pension systems. For example, studies such as Dong [2021] introduce a fuzzy Best-Worst method that uses fuzzy consistency for more accurate multi-criteria decision-making, which can be beneficial in evaluating the effectiveness of pension reforms. Moreover, the authors in Ahmed and Kilic [2019] point out that using an analytical hierarchical process together with fuzzy set theory allows for a better reflection of uncertainties.

Collectively, these research and methodological approaches enhance our understanding of the complex challenges and potential opportunities influencing pension systems amid demographic shifts and economic pressures.

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BIBLIOGRAPHY

- Act 650/2004 Coll. ON SUPPLEMENTARY PENSION SAVINGS AND ON AMENDMENTS TO CERTAIN ACTS. 2024. Bratislava, Slovakia: National Council of the Slovak Republic. [online] [cit. 12.11.2024]
<https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2004/650/>.
- ACT 43/2004 ON THE OLD-AGE PENSION SAVING AND AMENDMENTS TO SOME ACTS. 2024. [online] [cit. 12.11.2024] Bratislava, Slovakia: National Council of the Slovak Republic.
https://www.nbs.sk/_img/documents/_legislativa/_uplnezniazakonov/a43-2004.pdf.
- ACT 595/2003 Coll. ON INCOME TAX. 2003. [online] [cit. 20.9.2024]
<https://www.mfsr.sk/sk/dane-cla-uctovnictvo/prame-dane/dane-z-prijmu/legislativa-sr/zakon-dani-z-prijmov/>.
- ACT 129/2022 Coll. ON A pan-EUROPEAN PERSONAL PENSION PRODUCT. 2022. [online] [cit. 12.11.2024]
<https://nbs.sk/en/dohlad-nad-financnym-trhom/legislativa/legislativa/detail-d-okumentu/act-no-129-2022-coll-on-a-pan-european-personal-pension-product-pepp/>.
- ACT 352/2022 Coll., AMENDING Act No. 461/2003 Coll. ON SOCIAL INSURANCE. [online] [cit. 20.11.2024]
https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2022/352/vyhlasene_znenie.html.
- AHMED, F., KILIC, K. 2019. Fuzzy Analytic Hierarchy Process: A performance analysis of various algorithms. *Fuzzy Sets and Systems*, 362, 110-128.
<https://doi.org/10.1016/j.fss.2018.08.009>.
- BERSTEIN, S., MORALES SEPÚLVEDA, M. 2021. The role of a longevity insurance for defined contribution pension systems. *Insurance: Mathematics and Economics*, 99, 233-240.
<https://doi.org/10.1016/j.insmatheco.2021.03.020>.
- BOĎA, M., ÚRADNÍČEK, V. 2021. Stochastic analysis of uncertainty in significance weights in a multi-aspect evaluation. In *Slovak: Stochastická analýza neistoty vo váhach významnosti v rámci viacaspektného hodnotenia*. Belianum. Matej Bel Univerzity in Banská Bystrica. ISBN 978-80-557-1852-1.

- BRUNELLI, M., REZAEI, J. 2019. A multiplicative best-worst method for multi-criteria decision making. [online] [cit.3.3.2023] *Operations Research Letters*, 47, 1, 12-15.
<https://doi.org/10.1016/j.orl.2018.11.008>.
- BRÜNNER, A. 2008. Calculate eigenvalues and eigenvectors. [online] [cit.12.2.2022] https://www.amdt-bruenner.de/mathe/scripts/engl_eigenwert2.htm.
- DIRECTIVE (EU) 2016/2341 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2016 on the activities and supervision of institutions for occupational retirement provision (IORPs). 2021. [online] [cit.14.12.2021] Brussels, Belgium: Official Journal of the European Union L 354/37.
<https://eurlex.europa.eu/legalcontent/EN/TXT/PDF/uri=CELEX:32016L2341&from=EN>.
- DIJKSTRA, T.K. 2011. On the extraction of weights from pairwise comparison matrices. *Cent. Eur. J. Oper. Res.* 21, 103-123.
<https://doi.org/10.1007/s10100-011-0212-9>.
- DONG, J., WAN, S., CHEN, S.M. 2021. Fuzzy best-worst method based on triangular fuzzy numbers for multi-criteria decision-making. *Information Sciences*, 547, 1080-1104.
<https://doi.org/10.1016/j.ins.2020.09.014>.
- EDGE, C. E., COFFEY, M., COOK, P. A., WEINBERG, A. 2021. Barriers and facilitators to extended working life: a focus on a predominately female ageing workforce. *Ageing and Society*, 41(12), 2867-2887.
<https://doi.org/10.1017/S0144686X2000063X>.
- HINRICHS, K. 2021. Recent pension reforms in Europe: More challenges, new directions. An overview. Wiley, 409-422.
<https://onlinelibrary.wiley.com/doi/epdf/10.1111/spol.12712>.
- EUROSTAT. 2023a. Projected life expectancy by age (in completed years), sex, and type of projection [online] [cit.3.3.2023] Brussels, Belgium: European Commission.
<https://ec.europa.eu/eurostat/databrowser/view/tps00199/default/table?lang=en>.
- EUROSTAT. 2023b. Projected old-age dependency ratio. [online] [cit.3.3.2023] Brussels, Belgium: European Commission.
<https://ec.europa.eu/eurostat/databrowser/view/tps00200/default/table?lang=en>.
- EUROSTAT. 2023c. Total fertility rate. Brussels, Belgium: European Commission. [online] [cit.3.3.2023]
<https://ec.europa.eu/eurostat/databrowser/view/tps00199/default/table?lang=en>.
- GUBALOVÁ, J., MEDVEĎOVÁ, P., ŠPIRKOVÁ, J. 2021. The Global Pension Index of Slovakia. *Statistika*, 102(2): 117-137.
<https://doi.org/10.54694/stat.2021.38>.

- GUO, S., ZHAO, H. 2021. Fuzzy best-worst multi-criteria decision-making method and its applications. *Knowledge-Based Systems*, 121, 23-31.
<https://doi.org/10.1016/j.knsys.2017.01.010>.
- GROSS DOMESTIC PRODUCT. 2024. DATAcube. [online] [cit.3.4.2024]
https://datacube.statistics.sk/#!/view/sk/VBD_SK_WIN/eu0001re/v_eu0001re_00_00_00_sk.
- INTERNATIONAL LABOUR ORGANIZATION. 2024. [online] [cit. 25.9.2024]
<https://ilostat.ilo.org/methods/concepts-and-definitions/description-labour-force-statistics/>.
- INTERNATIONAL MONETARY FUND. [online] [cit. 27.9.2024]
https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/A_DVEC/WEOORLD.
- Information on Act No 129/2022 Coll. on a pan-European personal pension product and amending certain laws - 10/DZPaU/2022/I. 2022. [online] [cit. 27.10.2024]
https://www.financnasprava.sk/_img/pfsedit/Dokumenty_PFS/Zverejnovanie_dok/Dane/Novinky_leg/Priame_dane_uct/2022/2022.047.22_10_DZPaU_2022_I.pdf.
- JURČOVÁ, D. 2005. Glossary of demographic terms. INFOSTAT - Institute of Informatics and Statistics Bratislava, Demographic Research Centre. In *Slovak: Slovník demografických pojmov*. INFOSTAT – Inštitút informatiky a štatistiky Bratislava, Výskumné demografické centrum. [online] [cit. 27.10.2024]
http://www.infostat.sk/vdc/pdf/slovník_2verdd.pdf.
- KAŠČÁKOVÁ, A., KUBIŠOVÁ, L., NEDELOVÁ, G. 2015. Social and economic situation of silver generation in Slovakia. [online] 18th AMSE Conference – Applications of Mathematics and Statistics in Economics. [cit.14.11.2022]
http://amseconference.eu/history/amse2015/doc/Kascakova_Nedelova_Kubisova.pdf.
- KRČOVÁ, I., SAKÁLOVÁ, K., ZELINOVÁ, S. 2022. Modern methods of determining premiums in life insurance. In *Slovak: Moderné metódy určovania poistného v životnom poistení*. 1st edition. Brno: H.R.G.. ISBN 978-80-7490-281-9.
- LAKOTOVÁ, L. 2021. Long-term Sustainability of Pension Systems of European Union countries. In *Czech: Dlouhodobá udržitelnost penzijních systémů zemí Evropské unie, Politická ekonomie*, 69, 1, 48–72.
<https://doi.org/10.18267/j.polek.1307>
- LIST OF EUROPEAN COUNTRIES BY AVERAGE WAGE. [online] [cit. 23.01.2025]
https://en.wikipedia.org/wiki/List_of_European_countries_by_average_wage/#Net_average_monthly_salary.
- MADARAS, T. 2009. Multikriteriálna optimalizácia. Ústav matematických vied, Univerzita Pavla Jozefa Šafárika v Košiciach, Prírodovedecká fakulta. [online] [cit. 04.12.2024]
https://umv.science.upjs.sk/madaras/POV/POV_2.pdf.

- MELBOURNE MERCER GLOBAL PENSION INDEX. 2009. Melbourne Centre for Financial Studies. [online] [cit. 06.01.2020]
<https://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id:%22library/lcatalog/00460314%22;src1=sml>.
- MERCER CFA INSTITUTE GLOBAL PENSION INDEX 2020. Melbourne, Australia: Mercer and CFA Institute. [online] [cit.5.4.2021]
<https://cfasocietysingapore.org/wp-content/uploads/2020/12/MCGPI-2020-Full-Report.pdf>.
- MERCER CFA INSTITUTE GLOBAL PENSION INDEX 2021. Pension reform in challenging times. Melbourne, Australia: Mercer and CFA Institute. [online] [cit.15.2.2022]
https://www.lifeyrismal.is/static/files/images/Manadarpostar/2021-global-pension-index-report_web.pdf.
- MERCER CFA INSTITUTE GLOBAL PENSION INDEX 2022. Converting defined contribution benefits into better outcomes for retirees. Melbourne, Australia: Mercer and CFA Institute. [online] [cit.15.2.2022]
https://www.lifeyrismal.is/static/files/images/Manadarpostar/2021-global-pension-index-report_web.pdf.
- MERCER CFA INSTITUTE GLOBAL PENSION INDEX 2023. Feature chapter: The growing impact of AI on pension systems and their members. Melbourne, Australia: Mercer and CFA Institute. [online] [cit.15.2.2024]
https://www.lifeyrismal.is/static/files/images/Manadarpostar/2021-global-pension-index-report_web.pdf.
- MERCER CFA INSTITUTE GLOBAL PENSION INDEX 2024. An analysis and ranking of 44 pension systems around the world. Melbourne, Australia: Mercer and CFA Institute. [online][cit.15.2.2024]
https://www.lifeyrismal.is/static/files/images/Manadarpostar/2024-global-pension-index-report_web.pdf.
- MI, X., TANG, M., LIAO, H., SHEN, W., BENJAMIN, L. 2019. The state-of-the-art survey on integrations and applications of the best-worst method in decision making: Why, what, what for and what's next? *Omega*, 87, 205-225.
<https://doi.org/10.1016/j.omega.2019.01.009>.
- MINISTRY OF LABOUR, SOCIAL AFFAIRS AND FAMILY OF THE SLOVAK REPUBLIC. 2024a. Pillar II in figures. Bratislava, Slovakia: National Council of the Slovak Republic. In *Slovak: II. pilier v číslach*. Bratislava, Slovakia: Národná rada Slovenskej republiky. [online] [cit.12.1.2024]
<https://www.employment.gov.sk/sk/socialne-poistenie-dochodkovy-system/doc-hodkovy-system/ii-pilier-starobne-dochodkove-sporenie/>.
- MINISTRY OF LABOUR, SOCIAL AFFAIRS AND FAMILY OF THE SLOVAK REPUBLIC. 2024b. Pillar II in figures. Bratislava, Slovakia: National Council of the Slovak Republic. In *Slovak: III. pilier v číslach*. Bratislava, Slovakia: Národná rada Slovenskej republiky. [online] [cit.12.1.2024]
<https://www.employment.gov.sk/sk/socialne-poistenie-dochodkovy-system/doc-hodkovy-system/iii-pilier-doplňkove-dochodkove-sporenie/>.

- MU, E., PEREYRA-ROJAS, M. 2017. Practical Decision Making: an Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions V2. Springer International Publishing, Cham.
- NATIONAL BANK OF SLOVAKIA. 2024. Insurance corporations and pension funds statistics. [online] [cit.2.8.2023].
<https://nbs.sk/en/statistics/financial-institutions/insurance-companies-and-pension-funds/insurance-corporations-and-pension-funds-statistics/>.
- OECD. 2024. The OECD Global Pension Statistics Project: Overview of the Financial Wealth accumulated under Funded Pension Arrangements. [online] [cit.12.11.2023] <https://ideas.repec.org/a/oec/dafkab/519n6d57jf28.html>.
- OECD DATA EXPLORER. 2024a. Labour force population. [online] [cit.12.1.2024] [https://data-explorer.oecd.org/vis?lc=en&df\[ds\]=dsDisseminateFinalDMZ&df\[id\]=DSD_LFS%40DF_IALFS_LF_Q&df\[ag\]=OECD.SDD.TPS&dq=SVK.LF.._Z.Y._T.Y15T64..A&pd=2020%2C2023&to\[TIME_PERIOD\]=false&ly\[cl\]=TIME_PERIOD&pg=0&vw=tb](https://data-explorer.oecd.org/vis?lc=en&df[ds]=dsDisseminateFinalDMZ&df[id]=DSD_LFS%40DF_IALFS_LF_Q&df[ag]=OECD.SDD.TPS&dq=SVK.LF.._Z.Y._T.Y15T64..A&pd=2020%2C2023&to[TIME_PERIOD]=false&ly[cl]=TIME_PERIOD&pg=0&vw=tb).
- OECD DATA EXPLORER. 2024b. Labour force participation rate. [online] [cit.12.1.2024] <https://www.oecd.org/en/data/indicators/labour-force-participation-rate.html>.
- OECD DATA EXPLORER. 2024c. General government debt. [online] [cit.12.1.2024] <https://www.oecd.org/en/data/indicators/general-government-debt.html?oecdcontrol-3122613a85-var3=2020>.
- OECD DATA EXPLORER. 2024d. Employment: Length of maternity, parental and home care leave, and paid father-specific leave. [online] [cit.12.1.2024] <https://stats.oecd.org/index.aspx?queryid=54760>
- PENSIONS AT A GLANCE. 2019. OECD and G20 Indicators. Paríž, Francúzsko: OECD Publishing. [online] [cit.12.1.2024] <https://doi.org/10.1787/b6d3dcfc-en>.
- PENSIONS AT A GLANCE. 2023. OECD and G20 Indicators. Paríž, Francúzsko: OECD Publishing. [online] [cit.12.1.2024] <https://doi.org/10.1787/678055dd-en>.
- QIONG, M., ZESHUI, X. 2016. An intuitionistic fuzzy multiplicative best-worst method for multi-criteria group decision making. Information Sciences, 374, 224–239.
<https://doi.org/10.1016/j.ins.2016.08.074>.
- REZAEI, J. 2015. Best-worst multi-criteria decision-making, Omega, 53, 49-57.
<https://doi.org/10.1016/j.omega.2014.11.009>.
- REZAEI, J. 2016a. Best-worst multi-criteria decision-making method: Some properties and a linear model. Omega, 64, 126-130.
<https://doi.org/10.1016/j.omega.2015.12.001>.
- REZAEI, J. 2016b. BWM-Solver-4.xlsx.
<https://bestworstmethode.com/software/>.

- REZAEI, J. 2020. A Concentration Ratio for Nonlinear Best Worst Method. *International Journal of Information Technology & Decision Making*, 19, 03, 891-907. <https://doi.org/10.1142/S0219622020500170>.
- RUBIO, Y.A., RUBIO, L.A. 2024. Perceived social support of people over 60 years who care for their grandchildren. In Spanish: Apoyo social percibido de personas mayores de 60 años que cuidan de sus nietos. *Revista Española de Geriatria y Gerontología*, 59, 4. <https://10.1016/j.regg.2024.101490>.
- SAATY, T.L. 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15, 3, 234-281. [https://doi.org/10.1016/0022-2496\(77\)90033-5](https://doi.org/10.1016/0022-2496(77)90033-5)
- SAATY, T.L. 2005. *Theory and applications of the analytic network process: decision making with benefits, opportunities, costs, and risks*. RWS Publications. ISBN - 188860316X, 9781888603163.
- SAKÁLOVÁ, K., ZELINOVÁ, S. 2023. The Impact of the Environment of Rising Interest Rates and Inflation on Insurance Today. In Slovak: Vplyv prostredia rastúcich úrokových sadzieb a inflácie na poistenie v súčasnosti. *Trendy vo vzdelávaní študentov študijného programu Aktuárstvo. Trends in the Education of Students in the Study Program of the Actuarial Science: Reviewed Monographic Collection of Research Papers*. In Slovak: recenzovaný monografický zborník vedeckých prác. 74-78. Litomyšl: H.R.G., 2023.
- SORSA, V.P., VAN DER ZWAN, N. 2022. Sustaining the unsustainable? The political sustainability of pensions in Finland and the Netherlands, *Journal of European Social Policy*, 32, 1, 91-104. <https://doi.org/10.1177/09589287211035691>.
- PRIVATE PENSION ASSETS OF SLOVAKIA. 2024. *Statistics on insurance and pension funds*. Bratislava, SR: National Bank of Slovakia. [online] [cit.16.10.2024] <https://nbs.sk/statisticke-udaje/financne-institucie/poistovne-a-penzijne-fondy/statistika-poistovni-a-penzijnych-fondov/>.
- ŠPIRKOVÁ, J., KOLLÁR, I., SZŪCS, G., ZIMMERMANN, P. 2023. *Selected Payout Products of the Old-Age Pension Saving Scheme*. SpringerBriefs in Statistics. <https://doi.org/10.1007/978-3-031-23849-9>.
- SLOVAK STATISTICAL OFFICE. 2023. *Labour*. Bratislava. [online] [cit.26.9.2024] https://slovak.statistics.sk/wps/portal/ext/themes/demography/labour/metadata/!ut/p/z0/04_Sj9CPykyssy0xPLMnMz0vMAfjo8ziA809LZycDB0NDIycXQw8nXyDak18A4wMfM31C7IdFQHLnoFx/.

- SLOVAK STATISTICAL OFFICE. 2024a. STATdat. Population and age characteristics. In Slovak: Obyvateľstvo a charakteristiky veku. Bratislava. [online] [cit.17.9.2024]
https://statdat.statistics.sk/cognosext/cgi-bin/cognos.cgi?b_action=cognosViewer&ui.action=run&ui.object=storeID%28%22i5C596BD613BA4A6A9E92C3FB96F763F8%22%29&ui.name=Obyvate%20a%20charakteristiky%20veku%20%5Bas1001rs%5D&run.outputFormat=&run.prompt=true&cv.header=false&ui.backURL=%2Fcognosext%2Feps4%2Fportlets%2Fcommon%2Fclose.html&run.outputLocale=sk.
- SLOVAK STATISTICAL OFFICE. 2024b. STATdat. Economically active population by age. In Slovak: Ekonomicky aktivne obyvateľstvo podľa veku. Bratislava. [online] [cit.19.9.2024]
https://statdat.statistics.sk/cognosext/cgi-bin/cognos.cgi/b_action=cognosViewer&ui.action=run&ui.object=storeID%22i40A03AF2150C41DE8BE98D0C0C41A764%22&ui.name=Vekov%20zlo%20%20SR%20%20oblasti%20kraj%20okresy%20mesto%20vidiek%20%5bom7009r%5d&run.outputFormat=&run.prompt=true&cv.header=false&ui.backURL=%2Fcognosext%2feps4%2fportlets%2fcommon%2fclose.html#.
- SLOVAK STATISTICAL OFFICE. 2024c. STATdat. Employment rate. In Slovak: Miera zamestnanosti. Bratislava. [online] [cit.25.9.2024].
[https://statdat.statistics.sk/cognosext/cgi-bin/cognos.cgi?b_action=cognosViewer&ui.action=run&ui.object=storeID\(%22i8E020CDA1F7C4DA9A9EBA0310F1D6823%22\)&ui.name=Trh%20pr%20a%20%5bra1003rs%5d&run.outputFormat=&run.prompt=true&cv.header=false&ui.backURL=%2Fcognosext%2feps4%2fportlets%2fcommon%2fclose.html](https://statdat.statistics.sk/cognosext/cgi-bin/cognos.cgi?b_action=cognosViewer&ui.action=run&ui.object=storeID(%22i8E020CDA1F7C4DA9A9EBA0310F1D6823%22)&ui.name=Trh%20pr%20a%20%5bra1003rs%5d&run.outputFormat=&run.prompt=true&cv.header=false&ui.backURL=%2Fcognosext%2feps4%2fportlets%2fcommon%2fclose.html).
- SLOVAK STATISTICAL OFFICE. 2024d. STATdat. Deficit and debt of the SR in 2023. Bratislava. [online] [cit.26.9.2024].
https://slovak.statistics.sk/wps/portal/ext/products/informationmessages/inf_sprava_detail.
- SLOVAK STATISTICAL OFFICE. 2024e. DATAcube. Bratislava. [online] [cit.26.9.2024]
https://datacube.statistics.sk/#!/view/sk/VBD_SK_WIN/nu1401rs/v_nu1401rs_08_01_01_sk.
- SLOVAK STATISTICAL OFFICE. 2024f. Life tables. In Slovak: Tabuľky života. [online] [cit.16.10.2024]. <https://www.statistics.sk>.
- THURSTONE, L.L. 1927. A law of Comparative Judgment. *Psychology Review*, 34, 273-286.
- UNITED NATIONS: WORLD POPULATION PROSPECTS. 2022. Department of Economic and Social Affairs Population Division.
<https://population.un.org/wpp/>
- WANG, J.J., JING, Y.Y., ZHANG, Ch.F. 2009. Weighting methodologies in multi-criteria evaluations of combined heat and power systems, *International Journal of Energy Research*, 33, 1023-1039.
<https://doi.org/10.1002/er.1527>

- WORLD POPULATION REVIEW. 2024. Slovakia population. [online] [cit. 20.9.2024]
<https://worldpopulationreview.com/countries/slovakia>.
- ZELINOVÁ, S., SAKÁLOVÁ, K. 2023. The Impact of the Interest Rate on the Contractual Service Margin in Unit-Linked Insurance. In Slovak: Vplyv úrokovej miery na zmluvnú servisnú maržu v poistení Unit-Linked. Trendy vo vzdelávaní študentov študijného programu Aktuárstvo = Trends in the Education of Students in the Study Program of the Actuarial Science: Reviewed Monographic Collection of Research Papers. 112–120, Litomyšl: H.R.G., ISBN 978-80-7490-312-0.

APPENDIX

Eigenvalue matrix number versus number of indicators

Explanation of the concept of matrix eigenvalue and why it should be approximately as large as the number of indicators, Madaras [2009].

The preference magnitudes found by Saaty's comparison form the elements of the Saaty's matrix $S = (s_{ij})$, where s_{ij} represents an estimate of the weights of the i -th and j -th indicator, that is

$$s_{ij} \approx \frac{v_i}{v_j}. \quad (4.1)$$

The elements of s_{ij} on the main diagonal of the Saaty matrix are equal to 1. Ideally, for all $i, j, k = 1, 2, \dots, n$, the following should hold

$$s_{ij} = \frac{v_i}{v_j} = \frac{v_i}{v_k} \times \frac{v_k}{v_j} = s_{ik} \times s_{kj}. \quad (4.2)$$

A matrix with this property is called *consistent*, that is, its elements can then be obtained using only the elements from the first row.

If the Saaty matrix is consistent, then:

$$1 = s_{ii} = s_{ij} \times s_{ji}, \quad (4.3)$$

i.e. $s_{ji} = \frac{1}{s_{ij}}$, so the consistent Saaty matrix is reciprocal.

The Saaty matrix can be written in the form of the product

$$\begin{pmatrix} 1 & \frac{v_1}{v_1} & \dots & \frac{v_1}{v_n} \\ \frac{v_2}{v_1} & 1 & \dots & \frac{v_2}{v_n} \\ \dots & \dots & \dots & \dots \\ \frac{v_n}{v_1} & \frac{v_n}{v_2} & \dots & 1 \end{pmatrix} = \begin{pmatrix} v_1 \\ v_2 \\ \dots \\ v_n \end{pmatrix} \times \begin{pmatrix} \frac{1}{v_1} & \frac{1}{v_2} & \dots & \frac{1}{v_n} \end{pmatrix} \quad (4.4)$$

If we multiply the equation (4.4) on the right by the vector $(v_1, v_2, \dots, v_n)^T$, we get

$$\begin{pmatrix} 1 & \frac{v_1}{v_1} & \dots & \frac{v_1}{v_1} \\ \frac{v_2}{v_1} & 1 & \dots & \frac{v_2}{v_1} \\ \frac{v_3}{v_1} & \frac{v_3}{v_2} & \dots & \frac{v_3}{v_2} \\ \dots & \dots & \dots & \dots \\ \frac{v_n}{v_1} & \frac{v_n}{v_2} & \dots & 1 \end{pmatrix} \times \begin{pmatrix} v_1 \\ v_2 \\ \dots \\ v_n \end{pmatrix} = \begin{pmatrix} v_1 \\ v_2 \\ \dots \\ v_n \end{pmatrix} \times n \quad (4.5)$$

It follows that n is an eigenvalue of the matrix and the vector $(v_1, v_2, \dots, v_n)^T$ is its eigenvector. If the elements of the matrix are nonnegative, then the eigenvalues of the matrix S are nonnegative, and the sum of all the eigenvalues is exactly equal to the trace of the matrix, which is $1 + 1 + \dots + 1 = n$, so the other eigenvalues of the matrix are equal to 0.

Random index values in Saaty's method

Table 4.1 shows the values of the random index for the numbers of indicators $n = 3, 4, \dots, 9$. These values are part of the relation (2.2).

Table 4.1: Selected values of random index RI

n	3	4	5	6	7	8	9
RI	0.52	0.89	1.11	1.25	1.35	1.40	1.45

Source: Dijkstra [2021]

Best-Worst consistency index values

Table 4.2 shows the consistency index values for the Best-Worst method for the numbers of indicators and simultaneously for the maximum values within the scale $A_{BW}, n = 3, 4, \dots, 9$. These values are part of the relation (2.13).

Table 4.2: Consistency index values CI^{BW}

a_{BW}	3	4	5	6	7	8	9
CI^{BW}	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Source: Rezaei [2015]

Sustainability index for Iceland's pension system

Table 4.3: Sustainability index indicator scores and their total value based on weights determined by Saaty's exact method, s_i - score according to Mercer [2023]

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
s_i	10	10	6.50	10	9.40	7.20	10	4.50	2.50
w_i	0.25	0.22	0.05	0.08	0.04	0.13	0.03	0.18	0.02
x_i	2.500	2.200	0.325	0.800	0.376	0.936	0.300	0.810	0.050
index value = $10 \times \sum_{i=1}^9 x_i = 82.97$, where $x_i = w_i \times s_i$									

Source: the author

Table 4.4: Sustainability index indicator scores and their total value based on weights determined by approx. Saaty's method, s_i - score according to Mercer [2023]

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
s_i	10	10	6.50	10	9.40	7.20	10	4.50	2.50
	0.31	0.22	0.05	0.07	0.04	0.11	0.02	0.16	0.02
x_i	3.100	2.200	0.325	0.700	0.376	0.792	0.200	0.720	0.050
index value = $10 \times \sum_{i=1}^9 x_i = 84.63$, where $x_i = w_i \times s_i$									

Source: the author

Table 4.5: Sustainability index indicator scores and their total value based on weights determined by Thurstone method, s_i - score according to Mercer [2023]

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
s_i	10	10	6.50	10	9.40	7.20	10	4.50	2.50
	0.20	0.18	0.09	0.11	0.07	0.13	0.04	0.16	0.02
x_i	2.000	1.800	0.585	1.100	0.658	0.936	0.400	0.720	0.050
index value = $10 \times \sum_{i=1}^9 x_i = 82.49$, where $x_i = w_i \times s_i$									

Source: the author

Table 4.6: Sustainability index indicator scores and their total value based on weights determined by Best-Worst method, s_i - score according to Mercer [2023]

i	1	2	3	4	5	6	7	8	9
	I1	I2	I3	I4	I5	I6	I7	I8	I9
s_i	10	10	6.50	10	9.40	7.20	10	4.50	2.50
	0.31	0.19	0.06	0.08	0.05	0.10	0.05	0.13	0.03
x_i	3.100	1.900	0.390	0.800	0.470	0.720	0.500	0.585	0.075
index value $10 \times \sum_{i=1}^9 x_i = 85.40$, where $x_i = w_i \times s_i$									

Source: the author

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