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Turinys / Contents

EDITORIAL

The Vadyba / Journal of Management is a peer-reviewed applied sciences journal published by the Lithuania Business College. Since its establishment in 2002, the journal has continuously published scholarly articles, building a strong foundation of academic experience and earning international recognition. This year marks the journal's 24th anniversary. It is widely acknowledged by the international research community, and the number of foreign contributors continues to grow steadily. The current issue presented to readers is Volume 42. Only manuscripts that meet the rigorous standards of the Editorial Board are accepted for publication. The authors represent a diverse range of academic institutions in Lithuania and abroad, including Lithuania Business College, Kaunas University of Applied Sciences, and others, as well as Alexander Dubček University of Trenčín (Slovakia), Muğla Sıtkı Koçman University (Turkey), the College of Business Administration (Latvia), the Hungarian University of Agricultural and Life Sciences (Hungary), among others.

The Editorial Board seeks to ensure that published research encompasses a broad spectrum of topics in economics and management while maintaining relevance across industries and geographical contexts. Particular emphasis is placed on ongoing transformations in industries, human resource management, and managerial processes. Articles are selected based on these criteria, with the expectation that a focus on contemporary developments will foster scholarly discourse and contribute to the advancement of social sciences.

The studies included in this issue reflect the journal's interdisciplinary scope and international orientation.

The first article, authored by Angelė Lileikienė and Justinas Jonušas, examines the demand for nursing professionals in Lithuania and the European Union. Drawing on national statistical data, EU indicators, and international reports, the study explores both the current situation and future prospects. The authors highlight the impact of demographic trends, including population aging, the growing prevalence of chronic diseases, and rising patient expectations, on the demand for nursing services. The findings indicate that the shortage of nurses adversely affects the continuity of healthcare services, increases workloads, heightens the risk of professional burnout, and threatens both service quality and patient safety. These challenges are particularly pronounced in regional areas. The authors propose a comprehensive approach that includes strategic workforce planning at the national level, increased investment in nursing education, enhancement of the profession's attractiveness, improvement of working conditions, and the implementation of effective staff retention measures.

The second article, by Gabrielė Kubričenkaitė and Mantas Švažas, investigates the influence of organizational factors on work–life balance across different generations (X, Y, and Z). Based on a quantitative study involving 454 respondents, the authors identify significant generational differences in key organizational factors, such as organizational support, flexibility, and autonomy, as well as across all dimensions of work–life balance. Generation X demonstrates higher levels of negative work–life interference and lower levels of positive enrichment compared to Generations Y and Z. Although regression analysis did not reveal direct relationships between organizational factors and work–life balance dimensions, the findings underscore the importance of adopting differentiated management approaches that account for generational diversity. The study also highlights the need to develop adaptive human resource strategies that effectively balance structural stability with flexibility and employee well-being.

The third article, authored by Kristina Kozová, Adriana Grenčíková, Jana Španková, and Simona Kosáková, addresses the concept of the silver economy within the context of the Slovak Republic's labor market. The study explores both the challenges and opportunities associated with demographic aging, emphasizing the importance of active aging, age management, and intergenerational collaboration. Through a systematic literature review and bibliometric analysis based on Web of Science data from 2010 to 2024, the authors demonstrate that the silver economy

encompasses products, services, innovations, and the active participation of older individuals in the labor market. The findings highlight the critical role of age management in optimizing the labor potential of older populations, fostering inclusive workplaces, and supporting economic growth. The authors advocate for coordinated public policies and flexible organizational strategies aimed at transforming demographic challenges into economic and social capital, thereby contributing to the development of a longevity economy.

Together, these articles exemplify the mission of the Journal of Management: to publish research that is both academically rigorous and practically relevant. They address key challenges of 21st century management, including the sustainability of healthcare human resources, generational dynamics in work–life balance, and the transformation of demographic change into economic opportunity.

In addition to these primary contributions, the issue includes further studies that enrich the discourse on human resource management, demographic change, and organizational sustainability.

The journal is currently undergoing evaluation for indexing in the Scopus and Web of Science databases, which is expected to further enhance its academic visibility and strengthen its role in international scholarly communication.

On behalf of the Editorial Board, we warmly invite researchers to continue submitting their work, sharing insights, and contributing to the collective advancement of knowledge. Through such collaboration, we aim to expand the boundaries of management science and ensure that research meaningfully informs practice.

As it is not possible to review all contributions within this editorial, we encourage readers to explore the full range of articles presented in this issue, which is currently under consideration for inclusion in Scopus and Web of Science.

We invite scholars to actively publish in the journal, share their research findings and methodological insights, and engage in closer academic collaboration.

Prof. Dr. (H/P) Valentinas Navickas, Editor-in-Chief

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ENERGY POVERTY AND ITS SOCIAL, INCOME AND HOUSING DIMENSIONS: INSIGHTS FROM EUROSTAT DATA

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Abstract
Energy poverty is characterized by a household's inability to afford adequate energy services for a decent standard of living, extends beyond mere income deprivation, encompassing factors such as poor housing conditions, high energy prices, and inefficient energy consumption. Consequently, understanding and addressing energy poverty requires a holistic approach. energy poverty is also shaped by factors such as the energy efficiency of dwellings, the cost of energy, and individual energy consumption behaviors. Early scholarly contributions, notably Brenda Boardman's seminal work, established the foundational understanding of energy poverty as a condition where households are unable to afford adequate energy services to maintain a healthy and comfortable living environment. Building on Boardman's work, subsequent research has further refined these factors, integrating aspects like energy efficiency, housing quality, and the broader socio-economic context to provide a more nuanced understanding of energy poverty dynamics. The complexity behind the concept of energy poverty has led to varied measurement approaches globally, with no single, universally accepted standard for assessing energy poverty, leading to challenges in international comparability and policy implementation. Recognizing these complexities, the European Union has moved towards a more comprehensive understanding, seeking to integrate various dimensions into a cohesive Framework. The European Union's approach often incorporates metrics such as the inability to keep homes adequately warm, the presence of leaking roofs or damp walls, and high housing cost overburden rates to capture the lived experiences of energy-poor households. This research employs a methodology centered on four basic indicators extracted from Eurostat data, enabling a comprehensive examination of energy poverty's social, income, and housing quality components. Specifically, the selected indicators – percentage of total population living in a dwelling with structural defects, percentage of households unable to keep home adequately warm, and housing cost overburden rate – offer a framework for assessing the multifaceted nature of energy poverty across EU member states. The general trend indicates a slight improvement in the level of energy poverty across EU countries, albeit with persistent variations between the best and worst performers. While some policy measures may be effective broadly, others require refinement to address specific national or regional challenges. Furthermore, an increased focus on energy efficiency policies and renewable energy sources has been identified as a key driver for alleviating energy poverty, particularly in the long-term. This underscores the critical need for agile and adaptable policy responses that can swiftly address emergent challenges while fostering long-term resilience in energy systems.
Keywords: energy poverty, poor housing conditions, household income, home maintenance costs, energy efficiency.
JEL classification: Q48, Q58, I32

Introduction

Energy poverty, a multifaceted socioeconomic issue, has garnered increasing attention within the European Union due to its profound implications for household well-being, public health, and environmental sustainability (Oesterreich & Barej-Kaczmarek, 2024). This phenomenon, characterized by a household's inability to afford adequate energy services for a decent standard of living, extends beyond mere income deprivation, encompassing factors such as poor housing conditions, high energy prices, and inefficient energy consumption (Foster & Poston, 2023). The prevalence of energy poverty significantly impacts various facets of life, potentially leading to adverse health outcomes, social exclusion, and economic strain for affected households (Champagne et al., 2023). Consequently, understanding and addressing energy poverty requires a holistic approach that considers its complex interplay of social, economic, and structural determinants (Oesterreich & Barej-Kaczmarek, 2024). This paper aims to dissect the intricate components of energy poverty within the European context, focusing on social, income, and housing quality dimensions, utilizing comprehensive Eurostat data to provide an empirical analysis. Specifically, this study will investigate how indicators such as the percentage of the population living in dwellings with structural defects, the inability to keep homes adequately warm, and the housing cost overburden rate contribute to the overall burden of energy poverty across EU member states. This analysis will also explore the underlying mechanisms through which these factors exacerbate energy vulnerability, considering both demand-side and supply-side perspectives (Leipziger et al., 2023). Furthermore, the research will identify potential policy levers and interventions that could mitigate the impacts of energy poverty, emphasizing the importance of integrated strategies that span energy efficiency, social welfare, and housing policy. Such multifaceted approaches are crucial for fostering a just energy transition and ensuring that all citizens have access to affordable, clean, and reliable energy services, thereby contributing to the broader objectives of the European Green Deal. This examination acknowledges the absence of a universally agreed-upon EU-level definition for energy poverty, which complicates consistent measurement and policy formulation across member states, thereby necessitating the use of a dashboard of indicators rather than a single metric for comprehensive understanding (Bardazzi et al., 2023;

Leipziger et al., 2023). This analytical approach enables a nuanced assessment of the phenomenon, moving beyond simplistic income-based definitions to encompass structural and social vulnerabilities (Mochida et al., 2025) (Bardazzi et al., 2023). The complex interplay of these factors necessitates a multidimensional approach to assessment, moving beyond singular indicators to capture the true breadth and depth of energy deprivation across diverse socio-economic landscapes (Fabbri et al., 2023) (Spandagos et al., 2023). Recent academic discourse increasingly emphasizes the need for comprehensive frameworks that integrate socioeconomic data with environmental factors to accurately predict and address energy poverty (Kez et al., 2023). This study therefore provides an in-depth analysis of these components, drawing on Eurostat data from 2010, 2015, and 2022 to reveal temporal dynamics and spatial disparities in energy poverty across EU countries (Oesterreich & Barej-Kaczmarek, 2024). This research will also assess how various national policies, and socio-economic contexts influence these disparities, contributing to a more granular understanding of energy poverty's manifestations across the Union. This comprehensive approach aims to inform targeted policy interventions by identifying the most vulnerable populations and the specific drivers of their energy deprivation within different member states. The study states three hypotheses:

H1: Based on the available data, it is hypothesized that countries with a higher proportion of people living in dwellings with leaking roofs, damp walls, floors or foundations, or rot in window frames or floors will also exhibit a higher share of households unable to keep their homes adequately warm.

H2: It is further hypothesized that countries with higher housing cost overburden rates in urban areas are associated with a higher percentage of households unable to keep their homes adequately warm.

H3: In line with existing theoretical expectations, it is hypothesized that countries with higher levels of households' gross disposable income (log-transformed) will demonstrate lower rates of households unable to keep their homes adequately warm.

Literature review

The following literature review traces the evolution of the energy poverty concept within the European context, beginning with foundational work in the 1990s and progressing to contemporary understandings, while also delineating the pertinent European Union legal framework. It further explores the definitional challenges inherent in this complex phenomenon and elaborates on the composite indicators proposed by the European Union to measure its various dimensions (Oesterreich & Barej-Kaczmarek, 2024). Initially conceptualized primarily through an income-centric lens, the understanding of energy poverty has significantly broadened to incorporate multidimensional aspects, recognizing that financial hardship alone does not fully encapsulate the issue (Spandagos et al., 2023). This expanded perspective acknowledges that energy poverty is also shaped by factors such as the energy efficiency of dwellings, the cost of energy, and individual energy consumption behaviors (Castaño-Rosa et al., 2019). Furthermore, recent scholarships emphasize the importance of integrating technological and governance innovations to effectively address energy poverty, moving beyond traditional income and cost factors (Varo et al., 2022). Early scholarly contributions, notably Brenda Boardman's seminal work, established the foundational understanding of energy poverty as a condition where households are unable to afford adequate energy services to maintain a healthy and comfortable living environment (Yip et al., 2020). This initial conceptualization highlighted the interplay between low-income, high-energy costs, and inefficient housing structures as primary drivers of this multifaceted problem (Oesterreich & Barej-Kaczmarek, 2024). This framework was subsequently expanded to include six energy vulnerability factors, such as access and affordability (González-Pijuan et al., 2023). Building on Boardman's work, subsequent research has further refined these factors, integrating aspects like energy efficiency, housing quality, and the broader socio-economic context to provide a more nuanced understanding of energy poverty dynamics (Urquiza et al., 2019). For instance, the European Fuel Poverty and Energy Efficiency project further refined the definition, emphasizing the difficulty in maintaining an adequate standard of heat at a reasonable price, aligning with the citizen's right to appropriate temperature enshrined in the United Nations' Sustainable Development Goals (Oesterreich & Barej-Kaczmarek, 2024). This evolution underscores a shift from a purely economic definition to one that encompasses social and environmental dimensions, acknowledging energy poverty as a systemic issue with wide-ranging implications for public health, social equity, and climate action. This expanded perspective recognizes that energy poverty is not merely a matter of financial deficit but is deeply intertwined with broader infrastructural and environmental inequalities, necessitating a distinct analytical approach separate from general poverty studies (Simcock & Bouzarovski, 2023). The discourse has evolved to consider energy poverty as a distinct form of deprivation, emphasizing the need for targeted policies that address energy-specific vulnerabilities rather than solely relying on general anti-poverty measures (Jiang et al., 2019). This nuanced understanding highlights that vulnerability to energy poverty can stem from diverse factors, including inadequate household energy systems, specific needs due to illness or disability, and broader demographic characteristics, signifying a fluid state rather than a static condition (Bardazzi et al., 2023). Indeed, while the income-to-energy cost ratio often serves as a primary indicator, energy poverty is a complex issue extending beyond mere financial hardship, encompassing situations where energy bills consume a disproportionately high percentage of income or necessitate a reduction in household energy consumption to levels detrimental to health and well-being (Fabbri et al., 2023). This complex interplay of factors necessitates a multidimensional definition that incorporates social, economic, and housing quality components to accurately identify and address the various manifestations of energy poverty (Fabbri et al., 2023). This complexity has led to varied measurement approaches globally, with no single, universally accepted standard for assessing energy poverty, leading to

challenges in international comparability and policy implementation (Jiang et al., 2024). For instance, different indicators can identify varying numbers of households at risk and households with distinct characteristics, thus providing an ambiguous basis for academic studies and policy design (Deller et al., 2021). The ongoing debate surrounding appropriate metrics underscores the need for contextually sensitive indicators that can nonetheless be harmonized for broader comparative analyses (Tait, 2017). Recognizing these complexities, the European Union has moved towards a more comprehensive understanding, seeking to integrate various dimensions into a cohesive framework (Bardazzi et al., 2023). This proactive stance aims to bridge the definitional gaps and provide a methodological basis for monitoring and mitigating energy poverty across its member states (Pérez-Fargallo et al., 2020). This integrated approach acknowledges the multifaceted nature of energy deprivation, moving beyond a sole reliance on income metrics to encompass housing quality, energy efficiency, and broader socio-economic determinants (Castaño-Rosa et al., 2019). This evolution has led to the adoption of composite indicators, reflecting the multifaceted nature of energy poverty, driven by factors such as low-income, high-energy costs, poor energy efficiency of dwellings, and inadequate energy infrastructure (Josa & Aguado, 2019). Specifically, the European Union's approach often incorporates metrics such as the inability to keep homes adequately warm, the presence of leaking roofs or damp walls, and high housing cost overburden rates to capture the lived experiences of energy-poor households (Pérez-Fargallo et al., 2022).

The legal foundations of energy poverty within the European Union can be traced back to Directive 2009/72/EC, which first introduced the concept in a regulatory context. This directive highlighted essential elements such as the protection of vulnerable customers, the prevention or limitation of electricity disconnection for affected households, and the promotion of energy efficiency improvements in residential buildings. The regulatory framework evolved further in line with broader climate governance commitments. In alignment with the obligations adopted under the 2015 Paris Agreement, the European Council formally endorsed in December 2020 an enhanced climate ambition, requiring the European Union to reduce greenhouse gas emissions by at least 55% by 2030 compared with 1990 levels. This revision constitutes a substantial increase from the previous 40% target and is regarded as a prerequisite for achieving full climate neutrality by 2050. Meeting the revised 2030 target necessitates significant sectoral transformations, including a 60% reduction in emissions from buildings, a 14% decrease in their overall energy demand, and an 18% reduction in heating and cooling-related energy consumption across the Union. In response, the European Commission introduced the Fit for 55 legislative package, comprising amendments to existing directives and regulations, as well as newly established legal instruments, with the objective of ensuring that Member States implement the structural and policy measures required to attain the envisaged decarbonization trajectory. Identifying the geographical distribution and sociodemographic characteristics of the population groups most vulnerable to the EU Green Deal and its climate objectives for 2030 and 2050 is essential for ensuring a socially inclusive transition. This requirement has been formally acknowledged by the European Commission for the 2020–2025 policy agenda as a fundamental precondition for successful implementation. Within this evolving policy context, the intersection of distributive fairness challenges associated with the green transition and the impacts of the recent global energy crisis (2022–2023) has placed energy poverty at the center of contemporary economic policy discussions (Maier, 2025). Energy poverty therefore constitutes a recurring concern within the Fit for 55 package, given that several proposed measures are projected to place significant financial pressure on low-income households residing in inefficient buildings. Consequently, multiple provisions – formally embedded in binding EU directives – require Member States to implement safeguards and targeted interventions to prevent energy-poor households from being disproportionately affected by the progressing energy transition (Sáfián-Farkas, 2023). This framework was subsequently refined and expanded under Directive (EU) 2023/1791, which offers a comprehensive and explicit definition of energy poverty as a household's lack of access to essential energy services necessary to ensure adequate living standards and health. These services include, but are not limited to, sufficient heating, hot water, cooling, lighting, and electricity required for the operation of household appliances, while acknowledging that national socioeconomic conditions, existing social policies, and broader policy environments shape how the concept is operationalized across Member States. While several Member States have begun institutionalizing targeted responses, significant variation remains. In the Hungarian policy context, dedicated measures addressing energy poverty have not yet emerged, and the conceptualization of the phenomenon remains at an early stage. A nationally agreed definition is still absent, and no operational indicators have been established to systematically identify affected population groups. These gaps are further reinforced by the insufficient availability of relevant datasets, which poses a significant barrier not only to accurately assessing the scope and characteristics of energy poverty, but also to the effective design, implementation, and evaluation of policy interventions intended to mitigate its impacts (Sáfián-Farkas, 2023).

Methodology

These indicators are crucial for quantitative analyses that aim to pinpoint the precise drivers and manifestations of energy poverty across diverse European regions. The selection of appropriate indicators is paramount, as different measures can yield varying results regarding the prevalence and characteristics of energy poverty, necessitating careful consideration of their strengths and limitations in an analytical context. Furthermore, the choice of indicators significantly influences the design and effectiveness of policy interventions aimed at alleviating energy poverty, underscoring the need for validation and sensitivity analysis in their application. This research employs a methodology centered on four basic indicators extracted from Eurostat data, enabling a comprehensive examination of energy poverty's social, income, and

housing quality components. This quantitative approach facilitates the identification of patterns and correlations among these indicators, providing insights into the interdependencies between different dimensions of energy poverty. Specifically, the selected indicators – percentage of total population living in a dwelling with structural defects, percentage of households unable to keep home adequately warm, and housing cost overburden rate – offer a framework for assessing the multifaceted nature of energy poverty across EU member states. These specific indicators were chosen for their reliability and widespread use in social studies, reflecting established practices in assessing living conditions and deprivation within the European statistical system. Additionally, the use of Eurostat data ensures comparability across countries, which is essential for understanding regional disparities and for formulating pan-European policy recommendations. This approach allows for a granular analysis of how specific housing conditions and financial burdens contribute to the overall energy poverty landscape, moving beyond generalized assumptions to empirically grounded conclusions. The integrated nature of these indicators facilitates a comprehensive diagnostic assessment, allowing for the identification of specific vulnerabilities within different household typologies and geographic regions. Such detailed analysis is crucial for developing targeted interventions, as the effectiveness of energy poverty policies is contingent upon a precise understanding of its manifestations among various demographic groups. This research also considers the potential for hidden energy poverty, where households limit their energy consumption due to vulnerability, a nuanced aspect often overlooked by more conventional measures. Furthermore, the availability of static data and its comparability across time and space present important methodological considerations, especially when conducting analyses spanning multiple periods.

Study design and sample

This is an ecological, country-level, cross-sectional study using EU-27 Member States as observational units (N = 27). The analysis focuses on calendar year 2023 and relies only on four indicators extracted from Eurostat.

Data and variables

Four variables were used exactly as provided (percentages are in percentage points, 0–100):

1. Winter energy poverty (DV) – Percentage of households unable to keep the home adequately warm (Winter).
2. Urban cost burden – Housing cost overburden rate by degree of urbanization (cities) (Cost).
3. Income – Households' gross disposable income (million euro) (Income), transformed as logInc = log (Income) to reduce right skew and interpret effects as semi-elasticities.

Hypotheses 1–3 were tested based on the pairwise Pearson correlations. Analyses were conducted with SPSS.

Results

The analysis reveals significant disparities in energy poverty prevalence across EU member states, reflecting varied socio-economic conditions and energy market structures. For instance, countries with historically lower GDPs and less developed social protection systems often exhibit higher rates of energy poverty. This disparity underscores the complex interplay between macroeconomic factors and household-level energy vulnerability. Moreover, the highest synthetic measure of energy poverty in 2022 was observed in Luxembourg, influenced by real expenditure per capita, net social protection benefits for housing costs, final energy consumption per household, and electricity prices, alongside Malta, Croatia, and Slovenia. Conversely, Latvia, Romania, and Bulgaria demonstrated some of the lowest values in the same period, primarily due to their performance on indicators such as housing cost overburden and the inability to adequately warm homes. These findings highlight the heterogeneous nature of energy poverty across the EU, emphasizing the necessity of country-specific policy interventions tailored to local contexts rather than a one-size-fits-all approach. For example, some nations, such as Greece, have seen substantial increases in fuel poverty, particularly between 2010 and 2013, with significant public health implications, while Belgium, Denmark, Italy, and Greece recorded the highest risk of energy poverty in 2022. This spatial and temporal variation underscores the dynamic nature of energy poverty, influenced by a confluence of economic, social, and policy factors at both national and regional levels. Notably, significant reductions in energy poverty levels have been observed in countries like Latvia and Italy, while Nordic nations such as Sweden and the Netherlands consistently report the lowest incidences, reflecting social welfare systems and efficient energy markets. Such regional disparities further demonstrate that comprehensive policies addressing energy affordability, housing quality, and energy efficiency are crucial for mitigating energy poverty across the European Union. This is particularly evident when considering the varying definitions of energy poverty across member states, which can significantly influence reported prevalence rates and the targeting of intervention strategies.

Table 1. Pairwise Correlation Matrix of Study Variables

	Winter energy poverty (%)	**Bad living conditions (%)**	**Hosting cost overburden (%)**	**LOG (Income)**
Winter energy poverty (%)	1,00	0,378 (p=0,052)	0,046 (p=0,819)	0,064 (p=0,751)
Bad living conditions (%)		1,00	-0,051 (p=0,801)	0,106 (p=0,600)
Hosting cost overburden (%)			1,00	0,255 (p=0,200)
LOG (Income)				1,00

Sources: Pearson, Two-Tailed; EU-27 (2023)

Percentage of households unable to keep home adequately warm (%), Percentage of total population living in a dwelling with leaking roof/damp/rot, Housing cost overburden rate by degree of urbanization (cities) (%), LOG (Income) = LOG [Households gross disposable income (million euro)]
Source: own calculation based on the Eurostat (2025) data

In the 2023 EU-27 cross-section (N=27; Table 1.), **bad housing conditions** show a **moderate, positive** association with winter energy poverty (**r = 0.378, p = 0.052**), indicating only **marginal** evidence (at the 10% significance level) for H1. **Household income (log)** is essentially unrelated to winter energy poverty (**r = 0.069, p = 0.731**), so H2 is **not supported**. **Urban housing cost overburden** is also unrelated to winter energy poverty (**r = 0.046, p = 0.819**), so H3 is **not supported**. Together, the results point to **housing quality/energy efficiency** as the most plausible driver among the tested factors in 2023, while income and urban cost burden do **not** explain cross-country variation.

These variations highlight the crucial role of social safety nets and efficient energy markets in mitigating energy poverty. Understanding the nuanced interplay between household income and housing costs is therefore critical for developing effective energy poverty mitigation strategies. Furthermore, considering the multifaceted nature of energy poverty, which also encompasses housing quality and the ability to maintain adequate warmth, a comprehensive approach integrating housing policy with energy policy is imperative for sustainable improvement. This holistic perspective enables the development of targeted interventions that address the root causes of energy poverty, rather than merely treating its symptoms.

These indicators collectively underscore the multidimensional nature of energy poverty, extending beyond mere income constraints to encompass structural deficiencies in housing and the resultant inability to maintain thermal comfort. Such complexities necessitate a nuanced analytical framework that accounts for the interplay between socioeconomic factors, housing characteristics, and energy policy. Consequently, a deeper dive into the specific determinants of these indicators across different European Union member states is warranted to identify best practices and areas requiring urgent intervention.

According to winter energy poverty, the most fundamental thing is to examine the proportion of households that are unable to heat their homes to an adequate temperature, based on EUROSTAT data (see ilc_mdes01 online data code). The rate of this phenomenon, also known as winter energy poverty, in households – based on the average of the 27 member states of the European Union – has hardly changed between 2015 and 2023. Between 2015 and 2019, there was a slight decrease (from 9.6% to 6.9%), while between 2020 and 2023, there was an increase (from 7.5% to 10.6%). Looking at the data for a few countries, this trend can be observed in Belgium, the Czech Republic, Germany, Romania, and Austria. It is important to emphasize that only the trend has been highlighted, as individual Member States started from different values and arrived at different values over the years. However, it is a fact that winter energy poverty has decreased significantly in Bulgaria, Greece, and Lithuania. A recent study in Greece (Halkos-Kostakis, 2023) attributes these positive developments to targeted subsidies and energy efficiency investments (and access to better heating technologies). Building renovation programs play a prominent role in Lithuania (Streimikiene et al., 2021), but in Bulgaria (Wojewódzka-Wiewiórska et al., 2024), for example, positive change is significant in "only" a few objective indicators (energy efficiency investments). Without going into the underlying details, based solely on the raw data, Finland and Luxembourg were the least affected by winter energy poverty in 2023.

The presented Eurostat data on the inability to keep homes adequately warm reveal significant disparities across EU member states, reflecting diverse energy mixes, housing stock efficiencies, and socio-economic conditions. Specifically, countries in Southern and Eastern Europe consistently report higher percentages of households experiencing this form of energy poverty, underscoring the influence of prevailing building standards, climate variations, and income inequality on thermal comfort. Such persistent regional variations highlight the critical need for targeted policies that address both the structural deficiencies in housing infrastructure and the economic vulnerabilities of households, thereby fostering a more equitable distribution of energy security across the Union. Furthermore, the dynamic shifts observed in several countries, such as the notable increase in Germany and Ireland from 2020 to 2023, suggest the impact of external factors like energy market volatility and geopolitical events on household energy affordability. This necessitates a deeper quantitative analysis to pinpoint the precise drivers behind these fluctuations and to develop evidence-based interventions.

Let us examine the data in more detail based on the hypotheses outlined above:

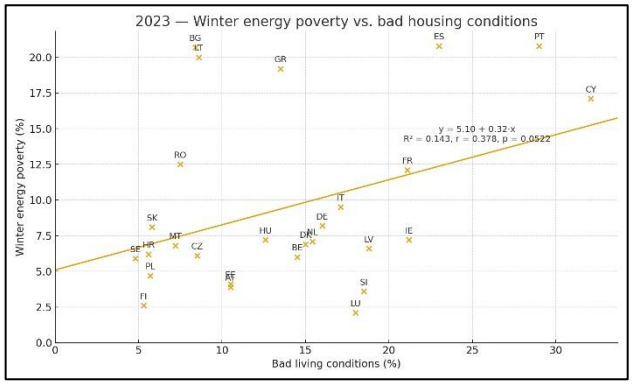

Fig. 1. Linear regression model between winter energy poverty and bad housing conditions
Source: own calculation based on the Eurostat (2025) data

Figure 1 shows the relationship between winter energy poverty (%) and poor housing conditions (%) in EU Member States (2023). Linear regression indicates a weak positive correlation ($r = 0.378$; $R^2 = 0.143$; $p \approx 0.05$). This means that although an increase in poor housing conditions is associated with a higher risk of energy poverty, the explanatory power of the relationship is low: the model explains only 14% of the variance. The weak correlation with climatic factors (although energy poverty is

paradoxically high in southern European countries, this is not due to the climate but to the poor condition of buildings and lower incomes), the application of regulated energy prices (as in Hungary), and the very different income situations of households can explain this.

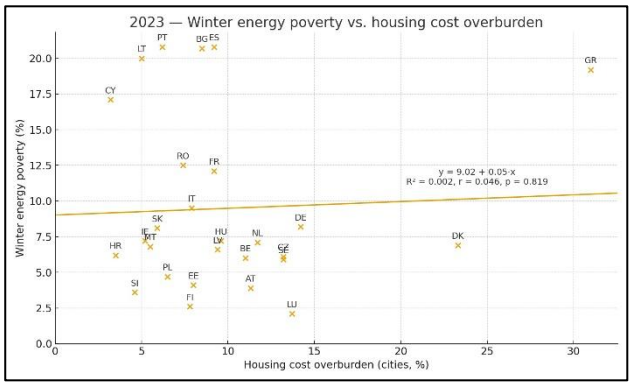

Fig. 2. Linear regression model between winter energy poverty and housing cost overburden
Source: own calculation based on the Eurostat (2025) data

The Figure 2 shows the relationship between winter energy poverty (%) and housing cost burdens. The results show that linear regression reveals virtually no correlation ($r = 0.046$; $R^2 = 0.002$; $p = 0.819$). This means that the extent to which urban households are burdened by excessive housing costs does not explain the development of energy poverty at all. One possible reason for this is that winter energy poverty specifically measures deprivation resulting from a lack of heating, which is not necessarily associated with high housing costs, as rent and maintenance costs also play a role. At the same time, it is important to emphasize the phenomenon of hidden energy poverty or forced energy deprivation. Low housing costs can be a misleading indicator, as some households deliberately deprive themselves of heating. This is why complex indicators (incorporating income, health, and subjective thermal comfort data) are needed to reveal hidden energy poverty. If, in addition to the above indicators, we also examine the gross disposable income of households in relation to winter energy poverty, we can categorize the individual EU member states into four groups. High energy poverty combined with low income, but not necessarily high housing costs, in Bulgaria, Portugal, Lithuania, Spain, Greece. Low energy poverty combined with high income levels and moderate housing costs in Luxembourg, Finland, Sweden, Denmark, Austria, and the Netherlands. The third group consists of "medium" countries, i.e. countries with medium energy poverty, medium income levels and medium housing costs, typically in Central Europe. In addition to Hungary, this group includes Slovakia, Poland, Romania, Croatia, and Latvia. Finally, the fourth group consists of outliers such as Greece (high income but relatively high energy poverty), Denmark (high income but low energy poverty), and Cyprus, where energy poverty is extreme despite relatively low-income levels.

However, the general trend indicates a slight improvement in the level of energy poverty across EU countries, albeit with persistent variations between the best and worst performers. This improvement, however, is often marginal and unevenly distributed, necessitating a deeper exploration of the underlying factors contributing to these disparities. For instance, countries like Ireland and Estonia have shown significant progress in reducing energy poverty indicators, while others, despite overall improvements, still exhibit areas of concern. This suggests that while some policy measures may be effective broadly, others require refinement to address specific national or regional challenges. Furthermore, an increased focus on energy efficiency policies and renewable energy sources has been identified as a key driver for alleviating energy poverty, particularly in the long-term. The production of green energy, for example, is becoming increasingly crucial due to its lower costs, which can directly reduce energy expenses and facilitate access for vulnerable households. However, challenges remain in ensuring equitable access to these renewable energy sources, particularly for low-income households which may face prohibitive upfront costs or limited access to financing mechanisms for energy efficiency upgrades. Moreover, the effectiveness of energy efficiency improvements in mitigating energy poverty is contingent upon their integration with broader social policies that address income inequality and housing quality. Many energy-poor households face exacerbated economic barriers, including higher risk and greater financial hurdles to implementing energy efficiency interventions. This reinforces the need for comprehensive policy frameworks that not only promote energy-efficient technologies but also provide financial assistance and targeted support to ensure that the benefits of such advancements reach all segments of the population, especially those most affected by energy poverty. The dynamic international situation, characterized by fluctuating energy carrier prices and internal socio-economic issues, further complicates the prediction of energy poverty trends, making even short-term forecasts prone to substantial error.

Conclusions

Taken together, the presented results underscore the critical need for agile and adaptable policy responses capable of addressing emergent challenges while supporting long-term resilience in energy systems. Such resilience necessitates a multi-faceted approach, integrating energy infrastructure with social support mechanisms and innovative technological solutions to safeguard against future energy shocks and ensure equitable access for all citizens. Moreover, the recent geopolitical shifts and their resultant impact on energy markets highlight the urgent need for strategies that enhance energy security and reduce reliance on volatile external sources (Oesterreich & Barej-Kaczmarek, 2024). This includes accelerating the transition to diversified and domestically sourced renewable energy, as well as implementing demand-side management strategies to optimize energy consumption (Oesterreich & Barej-Kaczmarek, 2024). These strategic shifts are paramount for fostering energy independence and insulating vulnerable populations from the unpredictable fluctuations of global energy markets (Oesterreich & Barej-Kaczmarek, 2024). Furthermore, continued governmental efforts in assisting households through both financial

interventions and energy efficiency improvements are essential for addressing energy poverty, alongside exploring additional measures to counteract the adverse effects of recent price and inflation increases (Spandagos et al., 2023). This includes not only direct financial aid but also investment in educational programs that empower consumers with knowledge about energy conservation and the benefits of adopting sustainable energy practices. Such initiatives, coupled with advancements in machine learning for predicting energy poverty, could provide more precise and less self-report-dependent interventions, allowing for better targeting of support measures and the integration of supplementary factors influencing energy consumption (Spandagos et al., 2023). This is crucial for overcoming targeting challenges and improving the efficacy of energy poverty alleviation schemes, particularly by enhancing transparency and evaluating the fairness potential of hypothetical interventions (Spandagos et al., 2023). Given the complex interplay of socio-economic and environmental factors, a comprehensive policy framework must therefore integrate energy justice principles with economic realities, ensuring equitable access to sustainable energy solutions for all households (Volodzkienė & Štreimikienė, 2024). Moreover, the emphasis on renewable energy sources within the European Green Deal underscores the strategic imperative to achieve climate neutrality by 2050, directly impacting energy policy and accelerating the shift away from fossil fuels (Hahn et al., 2025). This transition, however, must be managed carefully to prevent exacerbating energy poverty, particularly for vulnerable populations, necessitating inclusive strategies and equitable funding mechanisms (Lee et al., 2024). The Just Transition Fund and similar programs represent key financial instruments for assisting countries in achieving these goals, especially those struggling with social protection payments, energy efficiency, and supplier switching rates (Spandagos et al., 2023). This highlights the necessity of a coordinated policy response that balances ambitious climate targets with the imperative of social equity, ensuring that the benefits of the energy transition are broadly distributed. Achieving this balance requires continuous monitoring and evaluation of policy effectiveness, adapting strategies to address emerging challenges and ensuring that the transition genuinely leaves no one behind (Newell & Mulvaney, 2013; Kime et al., 2023). Specifically, policymakers must consider the distributive, procedural, and recognition justice dimensions of energy policy to foster equitable outcomes during decarbonization (Sovacool et al., 2019). This approach necessitates a paradigm shift from solely focusing on technological solutions to one that deeply embeds social equity and participatory governance in energy policy formulation (Healy & Barry, 2017).

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SILVER ECONOMY AS A NEW DIMENSION OF THE LABOUR MARKET OF THE SLOVAK REPUBLIC

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Abstract
The silver economy represents a new dimension of the labour market of the Slovak Republic, responding to demographic population ageing and changes in the age structure of the workforce. While traditional approaches to the labour market focused on a linear model of employment, current trends require flexible strategies integrating active ageing, age management, and intergenerational cooperation. This article analyses the theoretical and empirical foundations of the silver economy, identifies its economic, social, and organisational potential, and evaluates implications for strategic human resource management. A systematic literature review and bibliometric analysis of publications from the Web of Science database (2010–2024) confirmed that the silver economy represents a complex ecosystem encompassing products, services, innovations, and the participation of older workers in the labour market. The research highlights the importance of age management as a tool for optimising the work potential of the older population, supporting an inclusive working environment, and stimulating economic growth. The analysis also points to the need for coordinated public policies, flexible organisational strategies, and interdisciplinary approaches that will enable the effective utilisation of the potential of an ageing society. The silver economy can thus transform Slovakia's demographic challenges into economic and social capital, becoming a key component of the longevity economy and the sustainable development of the labour market.
KEY WORDS: silver economy, ageing workforce, labour market, active ageing, age management.
JEL classification: J14, J21, J24, M12

Introduction

Age transformation of the population is one of the most fundamental phenomena shaping society in the 21st century. European economies, including the Slovak Republic, are entering an era in which the long-term increase in life expectancy and declining fertility rates are fundamentally changing the population structure. This development has complex consequences – ranging from changes in consumer behaviour, through the transformation of social security systems, to adjustments in economic strategies and labour market policies (Bloom, Canning & Fink, 2011; Harper, 2023). According to Eurostat forecasts (2023), by 2050 more than one third of the population in the European Union will be over the age of 55, while the number of people of working age will decline significantly. This trend represents a serious challenge to the sustainability of public finances, pension systems, and the overall performance of labour markets. Demographic ageing is therefore not only a social phenomenon but also an economic challenge that requires new approaches to human resource management and to defining labour productivity in a changing age profile of society (Walker, 2021). In this context, increasing attention has been paid over the past decade to the concept of the silver economy. This term refers to a set of economic activities, products, and services focused on the needs of the older population, as well as a broader framework of economic participation of people in advanced age. The silver economy thus represents not only a consumer segment but also a space for new investment and innovation opportunities that can contribute to economic growth and social sustainability (Walker & Maltby, 2012; Naegele & Bäcker, 2019). According to the OECD (2019), the annual volume of "silver consumption" in the European Union is estimated at more than EUR 3 trillion, demonstrating that the older population is becoming a key factor of economic development. At the same time, however, it is increasingly evident that the ageing workforce poses a major challenge for organisations. Many enterprises face the retirement of skilled workers, a shortage of young employees, and a low rate of generational renewal. Older workers are often perceived as less flexible, slower to adapt to technological change, and may face age-based discrimination (Ilmarinen, 2012). These stereotypes, however, are not always justified – research confirms that older employees contribute to team stability, show higher levels of loyalty, and are able to effectively share knowledge with younger colleagues (Walker & Maltby, 2012). Therefore, modern HR management increasingly emphasises the need to implement age management – a system that makes it possible to take into account the different needs of workers across age groups. Age management includes not only the promotion of active ageing, but also the creation of appropriate working conditions, the development of lifelong learning, and the creation of opportunities for intergenerational cooperation. These approaches increase the employability of older workers and contribute to sustainable human resource management in an ageing society. The concept of the silver economy thus becomes an integral part of

economic discourse, with its importance extending beyond the framework of social policy (Ren, 2023). In the context of the labour market, it represents an opportunity for the development of new forms of employment, entrepreneurship, and innovation that reflect the changing age structure of the population. As Harper (2023) emphasises, a society with longer life expectancy also requires a paradigm shift in the understanding of productivity and the working life cycle – from a linear model (education–work–retirement) to a cyclical model that integrates education, reskilling, and work activity throughout the entire life course. In the case of the Slovak Republic, these trends are even more pronounced due to the combination of low fertility rates and the emigration of young people abroad. These factors lead to a reduction in labour potential and increase pressure on the adaptation of organisations and public policies alike. The Slovak labour market therefore faces a dual challenge – the ageing of the workforce and, at the same time, a shortage of qualified young workers. Addressing this situation requires strategic planning at both the state and enterprise levels, which will support the active participation of older workers, their reskilling, and the utilisation of the potential of intergenerational cooperation.

From this perspective, the silver economy has the potential to become not only a social but also an economic strategy. Its success depends on the ability of institutions and employers to adapt to demographic reality and to develop policies that support an inclusive working environment. As noted by the OECD (2020) and the European Commission (2021), the promotion of longer working lives, the improvement of working conditions, and flexible forms of employment are key factors in maintaining competitiveness in an ageing society.

The aim of this article is therefore to analyse the position of the silver economy as a new dimension of the labour market of the Slovak Republic and to identify its main implications for strategic human resource management. The study is based on current theoretical insights and empirical findings, placing particular emphasis on the practical aspects of applying age management, supporting active ageing, and developing intergenerational strategies within organisations.

Despite the growing interest in the silver economy and age management, there is still a lack of comprehensive studies that integrate macroeconomic, managerial, and socio-cultural perspectives for the Slovak labour market. In particular, empirical analyses examining the practical impacts of age management and the participation of older workers on workforce sustainability and economic growth in the Slovak Republic are missing. The research gap in the field of the silver economy and the labour market of the Slovak Republic arises from:

1. Lack of empirical studies at the national level: Most research on the silver economy focuses on an international or European context, while specific data and analyses for Slovakia are limited. There is a lack of systematic evaluation of the impact of an ageing population on the Slovak labour market and the effectiveness of age management in Slovak companies.
2. Interdisciplinary integration: Existing studies often examine either the economic or social aspects of the silver economy, but pay less attention to a combined perspective that links macroeconomic analysis, HR strategies, social inclusion, and technological innovation.
3. Practical implementation frameworks: Although theoretical models of age management and the longevity economy are well developed, practical recommendations and "best practices" for Slovak enterprises and public institutions that would enable the adaptation of an older workforce are lacking.
4. Impact of legislation and policies: There is a lack of research examining how existing or planned public policies and legal frameworks support or hinder the development of the silver economy in Slovakia.
5. Financial and social barriers of seniors: Deeper studies on the socio-economic situation of Slovak seniors, their work motivation, access to reskilling opportunities, and barriers to sustainable participation in the labour market are missing.

Literature review

Research into the phenomenon of the silver economy has, over recent decades, evolved into a multidisciplinary field that connects economic, managerial, and sociological perspectives on population ageing. While earlier works from the 1990s perceived demographic ageing primarily as a social problem and a fiscal burden, contemporary research interprets it as a transformative process and a potential source of economic growth, innovation, and labour market renewal (Harper, 2023; OECD, 2020). This shift in understanding reflects a broader change in how societies approach the relationship between longevity, productivity, and human capital development. Different research streams offer distinct yet complementary frameworks for understanding the dynamics of an ageing economy. Economic theories focus on the macroeconomic consequences of demographic change – their impact on growth, consumption, and the sustainability of public finances (Bloom, Canning & Fink, 2011). Managerial and organisational approaches examine the micro level, that is, the effects of workforce ageing on human resource management, leadership, and corporate culture (Ilmarinen, 2012; Walker & Maltby, 2012). In contrast, sociological and anthropological theories broaden the discussion to include dimensions of identity, social participation, and intergenerational solidarity (Laslett, 1991; Phillipson, 2013).

In recent years, an interdisciplinary approach has increasingly gained prominence, seeking to link these perspectives into a unified framework of sustainable demographic adaptation (Naegele & Bäcker, 2019; European Commission, 2021). This integrated view emphasises that the silver economy is not merely an economic concept, but a complex societal transformation that requires the coordination of public policies, the labour market, and organisational strategies.

The following sections therefore summarise four main scientific schools and their approaches to the issue

of the silver economy – economic, managerial-organisational, sociological, and integrated – highlighting their theoretical foundations, key representatives, and principal concepts.

1. **Economic school (macroeconomic and political-economy interpretations)**. This research school is based on a macroeconomic and structural framework in which the silver economy is interpreted as a new source of economic expansion and social stability in the context of demographic ageing. Theoretically, it draws on the tradition of human capital theory (Becker, 1964) and endogenous growth theory, which emphasise investment in education, health, and active ageing as determinants of long-term development.

Researchers within this school analyse the relationship between demographic structure, labour productivity, and public expenditure, pointing to the need to transform fiscal and social systems. The concept of productive ageing (Walker, 2021) is understood here as an economic model that transforms population ageing from a passive burden into an active factor of growth.

This approach represents a macroeconomic and structural research framework that focuses on the interconnections between demographic trends, economic growth, and socio-economic policies. The fundamental premise of this school is that population ageing is not only a demographic phenomenon, but also a systemic factor influencing economic performance, labour productivity, and the sustainability of public finances. It builds on human capital theory (Becker, 1964), according to which investments in education, health, and work ability are a key source of long-term growth, and on endogenous growth theory, which highlights the importance of innovation and knowledge for economic dynamism.

In the context of the silver economy, this approach interprets population ageing as a potential for the so-called longevity dividend – a form of demographic dividend that arises from the effective involvement of the older generation in the labour market and social life. Key concepts such as active ageing, productive ageing, and the social inclusion of older adults reflect efforts to overcome a passive understanding of old age and to integrate it into economic models as an active factor of growth and innovation.

From a methodological perspective, this school relies primarily on macroeconomic modelling, comparative analyses, and projections of demographic trends, which make it possible to assess the impact of ageing on productivity, public expenditure, and economic stability. The aim of such an approach is to identify long-term linkages between demography and economic development and to formulate public policies that support inclusive and sustainable economic growth in an era of population ageing.

2. **Managerial-organisational school (HR management and age management)**. This school focuses on the microeconomic and organisational level, examining how population ageing affects personnel strategies, organisational culture, and work motivation. It is grounded in the paradigm of strategic human resource management and the behavioural economics of labour, which analyse employee adaptability and the need for flexible forms of work.

At the core of this approach is the concept of age management, which integrates principles of inclusive management, lifelong learning, and intergenerational knowledge transfer (Ilmarinen, 2012; Walker & Maltby, 2012). These approaches emphasise that the ability of organisations to maintain the work ability of older employees is a fundamental prerequisite for competitiveness in the era of digitalisation and Industry 4.0 (Schuller, 2017).

This approach represents a microeconomic, behavioural, and organisational perspective that examines the consequences of population ageing at the level of enterprises and institutions. Its core belief is that demographic changes represent not only a challenge for the labour market, but also an impetus for strategic transformation in the field of human resource management. The key theoretical foundations of this school are organisational learning theory and the work ability concept, which emphasises the need to maintain a balance between job demands and the individual capabilities of workers throughout the entire life cycle (Ilmarinen, 2012).

Within this approach, the age management paradigm is developed, based on the principles of inclusive management, lifelong learning, and intergenerational knowledge transfer. The aim is to support the sustainable employability of older workers, increase their adaptability to technological changes, and at the same time prevent the loss of qualifications due to premature exit from the labour market (Walker & Maltby, 2012). Concepts such as lifelong learning, inclusive leadership, and intergenerational knowledge transfer are in this context considered strategic tools for strengthening organisational competitiveness and workforce stability in the era of digitalisation and Industry 4.0 (Taylor & Earl, 2016; Schuller, 2017).

From a methodological perspective, the managerial-organisational school is oriented towards qualitative research on organisational processes, case studies, and HR diagnostics, which make it possible to identify barriers and opportunities associated with workforce ageing. This approach places emphasis on the empirical verification of strategies aimed at maintaining work ability, supporting intergenerational cooperation, and developing corporate cultures that take age diversity into account. The goal is to create an environment in which older workers become active carriers of knowledge, stability, and continuity of organisational development.

3. **Sociological-anthropological school (social and cultural dimension of the silver economy)**. This approach is rooted in traditional social gerontology and the anthropology of ageing, which understand ageing as a cultural and social process shaping the identity, values, and life strategies of the older population. Researchers such as Laslett (1991) and Phillipson (2013) developed the concept of the so-called third age – a life stage following exit from the labour market in which individuals actively engage in social, cultural, and civic life.

The modern orientation of this school emphasises that the economic activity of older people has not only material, but also symbolic and social significance (Walker, 2021). The paradigm of active ageing is here understood as a form of social participation and meaningful living, rather than merely as an extension of working life.

This approach represents a socio-cultural and humanistic research framework that analyses population ageing as a complex social phenomenon extending beyond the economic and labour dimension. It draws on the tradition of social gerontology and the anthropology of ageing, which understand old age not as a passive period of decline, but as a socially constructed life stage associated with new forms of identity, participation, and cultural value (Laslett, 1991; Phillipson, 2013). The fundamental theoretical starting point here is the concept of the so-called third age, which defines the period after exit from the labour market as a phase of active self-realisation, education, and social contribution of the individual.

The sociological-anthropological school emphasises that the economic activity of the older generation also has symbolic and cultural significance – it reflects a shift in the understanding of the value of work, solidarity, and intergenerational relationships. Walker (2021) points out that the concept of active ageing should not be reduced solely to economic participation, but should be perceived as a process of social inclusion, mutual care, and intergenerational dialogue. This approach also raises the issue of the quality of life of older people, which is determined not only by material security, but also by a sense of meaningfulness, recognition, and social belonging.

From a methodological perspective, this strand relies primarily on qualitative research methods, such as ethnographic studies, in-depth interviews, and surveys of seniors' value orientations. These approaches make it possible to capture subjective experiences, attitudes, and cultural representations of ageing that quantitative models often overlook. The findings of research within this school contribute to the reassessment of the social position of older people and to the shaping of inclusive ageing policies that emphasise dignity, participation, and meaningful social inclusion in later stages of life.

4. **Integrated and interdisciplinary school (linking macro- and micro-levels)**. The integrated school represents a synthesis of economic, managerial, and social perspectives, striving to create a comprehensive model of sustainable demographic adaptation. Scholars such as Naegele (2022), Harper (2023), and the OECD (2019) emphasise the need for a coordinated societal response to population ageing through the interconnection of public policies, the labour market, educational institutions, and the private sector.

At its core is the paradigm of the longevity economy, which interprets longer life as a source of innovation, economic stability, and social cohesion (European Commission, 2021). This approach transcends traditional dichotomies between economic efficiency and social inclusion and promotes multidisciplinary solutions based on cross-sectoral cooperation and long-term sustainability.

This approach represents a synthesis of economic, managerial, and sociological perspectives and seeks to create a holistic framework for understanding and managing demographic change. It is grounded in the belief that the process of population ageing cannot be explained or addressed within a single discipline – it requires a coordinated integration of knowledge from economics, sociology, demography, public policy, and management. Proponents of this school (e.g. Naegele, 2022; Harper, 2023; OECD, 2019) emphasise the need to link the macro level of public policies with the micro level of organisations and individuals, thereby giving rise to a new concept of sustainable management of an ageing society.

The foundation of this approach is the paradigm of the "longevity economy", which interprets the extension of human life as an economic, social, and innovative potential. A longer life cycle creates new opportunities for the labour market, healthcare, education, and the technological sector, while requiring a shift in approaches to employment and social security (European Commission, 2021). From this perspective, ageing is understood not as a problem, but as a driving force of economic transformation that can support value creation, innovation growth, and the development of new markets focused on the needs of the older population.

The integrated approach also emphasises systemic cooperation between sectors – linking economic strategies with policies of social inclusion, education, and healthcare. This framework promotes the concept of sustainable workforce development, which supports a balance between efficiency and social justice, as well as cross-sector cooperation among the state, businesses, and civil society. At the same time, it highlights the need to build resilient ageing societies, that is, societies capable of adapting to demographic change through long-term planning, education, and innovation.

Methodologically, this approach relies on systems modelling, comparative analyses, and strategic foresight studies, which make it possible to anticipate future consequences of demographic trends and to design multi-level policies. The goal of the integrated framework is to create a sustainable workforce development model that is simultaneously economically viable, socially inclusive, and culturally adaptable. In this way, the interdisciplinary school becomes the foundation for a modern paradigm of the silver economy, which combines economic efficiency with quality of life in an ageing society.

Methodology

The aim of the methodological section is to clarify the procedure through which the research on the issue of the silver economy as a new dimension of the labour market of the Slovak Republic was conducted. As the article has the character of a scientific literature review, the methodological framework focuses on the systematic analysis and synthesis of scientific knowledge from domestic and international sources.

The chosen approach is based on the principles of qualitative secondary research, specifically the method of a systematic literature review. The aim was to identify, analyse, and compare theoretical approaches, models, and empirical findings related to the development of the silver economy, demographic ageing, and their impact on the labour market and human resource management. The review methodology was grounded in the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which ensures transparency and replicability of the research process. This approach enables not only the synthesis of existing knowledge, but also the identification of research gaps and perspectives for further research.

For the selection of relevant literature, the Web of Science database was chosen and limited to the years 2010–2024, as this period represents a phase of intensive technological development across various sectors, including the labour market, making it a relevant time frame for analysing current trends and impacts. The growing number of publications illustrated in Figure 1 reflects the increasing scientific and practical interest in the issue of the silver economy. This trend indicates that population ageing and its economic consequences are becoming an increasingly important topic for research and policy-making in the areas of the labour market and social security.

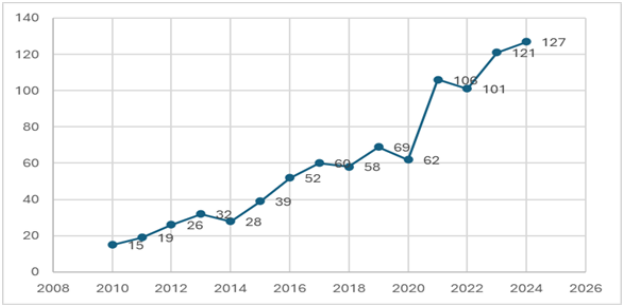

Fig. 1. Research trend of the "silver economy" in the WoS database in the years 2010–2024
Source: own elaboration

The procedure through which we arrived at the final number of articles is presented in Figure 2, the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This model was designed to transparently and systematically report the process of identifying and processing literature reviews. It was developed based on the methodology outlined in other publications (Page et al., 2021; Moher, 2009).

The main database used in this study is Web of Science (WoS) by Clarivate. WoS is a widely used database among researchers due to its extensive coverage of scientific literature across various fields. Using WoS, we filtered contributions in order to ensure a relevant and representative sample. The use of WoS and filtering criteria ensured reliable and relevant sources for our analysis. The data used were collected on 21 November 2025. Figure 2 presents the data collection process according to individual criteria.

The term silver economy appears a total of 3,529 times in the following databases: Web of Science Core Collection, BIOSIS Citation Index, Current Contents Connect, Data Citation Index, Derwent Innovations Index, Grants Index, KCI-Korean Journal Database, MEDLINE®, ProQuest™ Dissertations & Theses Citation Index, and SciELO Citation Index. It is important to note that the English language is a global language and is generally recognised as the primary language for publishing scholarly contributions. English is the predominant language used in the primary part of the records, with a total of 3,385 studies recorded in this language. As a result of this significant and dominant volume, English became the main language used in the filtering process, while all other languages were excluded. Subsequently, the studies were sorted according to the criteria listed in Figure 2, and a total of 31 studies were included in the final analysis.

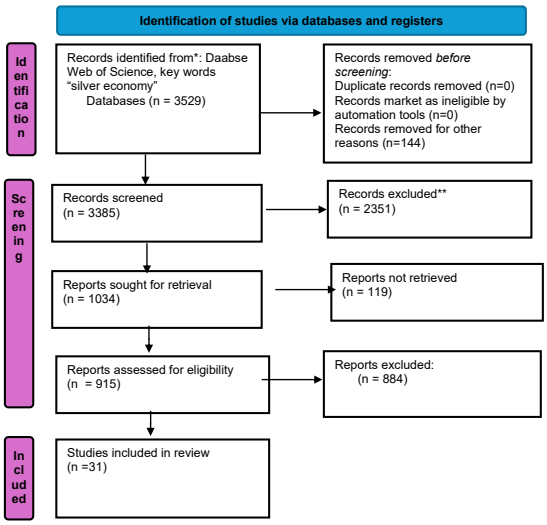

Fig. 2. PRISMA diagram
Source: own elaboration

We processed a visualisation created using the VOSviewer software, which illustrates the structure and thematic interconnections in research focused on the silver economy. The keyword map reveals several distinct thematic clusters that reflect the multidisciplinary nature of the examined topic. For the purposes of conducting bibliographic analyses, the VOSviewer software was used. VOSviewer is a free software tool for constructing and visualising bibliometric networks from journals or individual publications. Data can be constructed based on citation relationships, bibliographic coupling, co-citation, or co-authorship. The software offers a text mining function that can be used to visualise networks of co-occurrence of important terms from the scientific literature. This software links keywords using association strength (by default). Association strength is used to normalise the strength of links between items (DeGroote, 2023).

The keyword "silver economy" is closely linked primarily to terms related to demographic trends, technological development, and the economic implications of population ageing. Another cluster (yellow) includes terms such as population aging, ageing population, elderly, and ageing. This linkage represents the demographic foundation of the entire

research field and indicates that the issue of the silver economy is primarily anchored in the study of population ageing. At the same time, there is another linkage (green cluster) that groups terms related to economic growth, innovation, and the labour market (growth, technology, innovation, employment). This connection with the central concept suggests that a significant part of the literature focuses on economic opportunities and the innovation potential arising from an ageing population.

The concept of the silver economy is also associated with economic factors, represented in the figure by terms such as inflation, trade, monetary policy, consumption, and uncertainty (red cluster). This clearly indicates the macroeconomic context within which the silver economy is analysed. The presence of these terms suggests an increased interest in external economic factors influencing the behaviour of older consumers and macroeconomic stability.

At the same time, we observe additional smaller clusters related to performance, management systems, and the impacts of crises (e.g. COVID-19) (blue), as well as clusters focused on governance, institutions, and globalisation (purple). Altogether, these complement the picture of the complexity of this research terrain and underscore that issues of governance, institutional frameworks, and global trends are increasingly being integrated into the discussion of the silver economy.

The visualisation indicates that research on the silver economy is characterised by a high degree of interdisciplinarity. Key concepts are grouped into thematic clusters that connect demographic, technological, economic, and socio-institutional aspects of ageing. This structure supports the interpretation of the silver economy as a dynamically developing field that goes beyond traditional disciplinary boundaries and requires integrated analytical approaches.

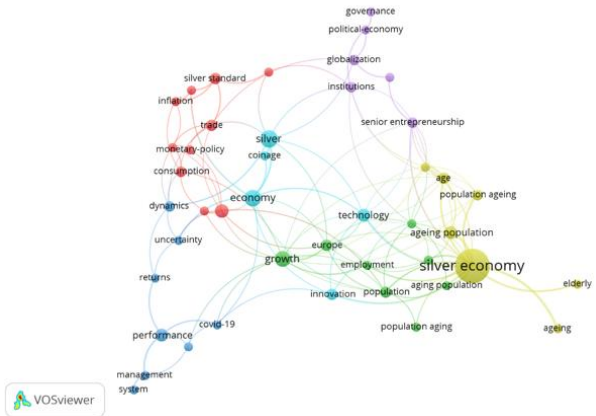

Fig. 3. Map of keywords
Source: own elaboration

Limitations

This study is based on a systematic literature review and bibliometric analysis using the Web of Science database and a defined set of search filters (language, document type, publication years, and subject categories). As a result, several limitations should be acknowledged. First, restricting the search to a single database and primarily to English-language peer-reviewed journal articles may have led to the exclusion of relevant studies published in other databases, books, policy reports, or national publications, including Slovak-language sources that may provide important local context. Second, bibliometric analysis and keyword co-occurrence mapping identify structural relationships and thematic trends in the literature but do not evaluate causal relationships or the practical effectiveness of specific labour-market or HR policies. Third, the selected time period (2010–2024) may underrepresent earlier foundational research on ageing and labour markets. Finally, as a secondary research design based exclusively on existing literature, the study does not include primary empirical data from Slovak organisations or workers. Therefore, the conclusions should be interpreted as a theoretical and conceptual synthesis rather than direct empirical evidence, and further primary research is recommended to validate the findings in the specific context of the Slovak Republic.

Findings

Among the most cited studies (42 citations) is the study by Rogelj and Bogataj (2019), who focus on population ageing in relation to rising expenditures on healthcare and long-term care in ageing societies. They provide an overview of the social infrastructure of the silver economy and emphasise that the development of infrastructure – healthcare, social, and educational – is a prerequisite for transforming the economy into a "silver-friendly" model. Another study by Wang et al. (2022) focuses on the negative effects of an ageing population and examines the consumer potential of older people. The study by Ren et al. (2023) is closely related to the development of the silver economy, which represents a set of economic activities, products, and services responding to the needs of an ageing population. In the context of China, which has faced rapid demographic ageing in recent decades, the domestic care sector has gained crucial importance as one of the key segments of the silver economy. The rapid growth in demand for senior care services simultaneously reveals structural weaknesses of the sector, particularly a low level of formalisation, high transaction costs, information asymmetry, and fluctuating service quality.

Ogawa et al. (2021) focus on population ageing in Asia, which fundamentally alters the age structure and, consequently, the sources of economic growth, a development that is crucial for age management and the expansion of the silver economy. They note that the first and second demographic dividends previously supported growth through a larger share of the working population and higher savings; however, in rapidly ageing countries (Japan, Korea, Taipei), pressure on public transfers is increasing while the importance of family transfers is declining. The authors introduce a "silver" third dividend, which arises from the utilisation of the labour potential of healthy seniors—this constitutes the core of modern age management. Through calculations, they demonstrate that in Japan this potential can significantly contribute to macroeconomic growth. The study thus confirms that

workplace adaptation for older employees and the development of the silver economy are strategically essential for sustainable growth in ageing societies. Similarly, Heshmati et al. (2019) emphasise that older generations are often particularly vulnerable and that it is important to create working conditions and social policies that support active ageing. The identified inequality factors—technological change, education, globalisation, and labour market reform—indicate that without targeted policies, the older workforce may be pushed to the margins, thereby weakening the potential of the silver economy as well. The text also highlights the need for reforms in taxation, education, and the labour market, which must be designed to support equal opportunities, including those for older employees. Overall, it shows that inclusive growth and effective age management are interlinked conditions for sustainable socio-economic development. In contrast, Barković et al. (2024) conclude that modern seniors are healthier, more active, and possess substantial purchasing power, making them a significant economic force and supporting the dynamic growth of the silver economy. Their study emphasises that global population ageing fundamentally changes demographic structures and the economic environment, creating new challenges and opportunities for age management and the silver economy. Overall, the text demonstrates that supporting silver entrepreneurship and age-friendly policies is key to productively managing demographic change and building a sustainable, inclusive economy.

Research findings on the macroeconomic aspects of the silver economy have expanded significantly over the past decade, with authors increasingly pointing to the transformative nature of demographic ageing for modern economies. Initially, the concept of the silver economy was understood primarily as economic activity related to the consumption of goods and services intended for the older population. Today, however, this concept has shifted towards a comprehensive economic model that also includes the participation of older people in the labour market, the development of innovations, technological solutions, and new forms of social entrepreneurship (Harper, 2023; OECD, 2019).

According to the works of Bloom, Canning, and Fink (2011), population ageing can be interpreted not only as a risk to fiscal sustainability, but also as a driver of economic growth – provided that society is able to effectively utilise the human capital of older generations. In this sense, the concept of the silver economy builds on endogenous growth theory, which emphasises the role of knowledge, experience, and innovation as driving forces of economic productivity.

Within the European context, this concept has gained institutional support through initiatives of the European Commission, particularly the document "Green Paper on Ageing" (2021), which defines the silver economy as a strategic area of social and economic policy. Based on OECD recommendations (2020), several EU Member States are focusing on linking employment policies, social security systems, and lifelong learning in order to support productive ageing and increase the level of economic participation of the population aged 55+.

Discussion

An analysis of research trends in the field of the silver economy has confirmed that it is a dynamically developing interdisciplinary area that goes beyond the traditional understanding of ageing as exclusively a social or demographic problem. The scientific discourse of the past decade points to a paradigmatic shift from the concept of passive ageing to a model of active, productive, and inclusive ageing, which brings not only social but also economic benefits (Harper, 2023; OECD, 2019).

The discussion within the framework of the four identified theoretical schools – economic, managerial-organisational, sociological-anthropological, and interdisciplinary – has shown that all approaches converge on one key point: population ageing can be transformed into a source of development if it is addressed strategically. From an economic perspective, the silver economy represents potential for faster growth and labour market stabilisation; from a managerial perspective, it creates space for innovation in HR strategies and age management; and from a sociological perspective, it supports a shift in societal attitudes towards old age, intergenerational dialogue, and social cohesion.

By combining these approaches, a new interdisciplinary framework of the longevity economy emerges, which is aligned with the United Nations Sustainable Development Goals (Agenda 2030) and with European Union policies on active ageing and inclusive growth. Within this framework, older people are perceived not as passive recipients of social services, but as active participants in the labour market, consumers, and carriers of innovation, whose experience represents significant economic and cultural value (Walker & Maltby, 2012; Naegele & Bäcker, 2019).

The sources together create a robust picture showing that:

1. **The silver economy is a complex ecosystem** that encompasses services, the labour market, consumption, technologies, and social innovations (Barković Bojanić, 2024; Krzyminiewska, 2020; Cucculelli, 2023). The development of the silver economy will be one of the expected megatrends of the economy. Activities of the silver industry, social innovations, gerontechnologies, and senior entrepreneurship are prerequisites for improving the standard and quality of life of the older generation. The silver economy can be a significant driver of development if it is based on ethical principles supporting social and economic inclusion, as well as countermeasures against stereotypes, age discrimination, and social exclusion. Age management is a key tool that enables societies to productively integrate the ageing population into the work process. At the same time, the authors emphasise that this issue requires a broader analysis in terms of emerging ethical challenges, which opens space for further research.

2. **Age management as a key tool for integrating the ageing population,** which can mitigate labour shortages and support economic growth (Knapińska,

2023; Warwas, 2019). Willingness to work among older workers is increasing; however, they face significant barriers, including age discrimination and limited access to digital job-search tools. At the same time, age management research has revealed differences between traditional and knowledge-oriented organisations, particularly in perceptions of older employees and in the formality and scope of the implementation of age management tools. This indicates the need to develop and coordinate age management strategies that support the professional activity of seniors and optimise their work potential, while the implementation of such measures is crucial not only for increasing the labour participation of older people, but also for the sustainable development of the labour market in the context of an ageing population.

3. **Working pensioners as a strategic potential,** representing a significant factor that can mitigate labour shortages and support economic growth. International studies (Ogawa et al., 2021; Jajko-Siwek, 2024) show that population ageing and changes in age structure have a substantial impact on economic growth through demographic dividends. Analyses of selected economies indicate that utilising the unused labour capacity of healthy older individuals – the so-called "silver" or "third demographic dividend" – can have a significant macroeconomic effect, with Japan already achieving notable results. At the same time, research in the European context emphasises that the financial well-being of seniors is closely linked to their incomes and available financial resources, while socio-economic factors such as housing and food costs significantly affect the ability of older people to meet basic living needs. These findings underline that supporting the professional activity of seniors and optimising their work potential will not only contribute to sustainable economic growth, but can also improve the financial situation and overall quality of life of older people.

4. **Public policies and formal institutional frameworks are** essential for the sustainability of this system. Since the second half of the 20th century, countries have faced the challenge of balancing the provision of extensive social benefits with the promotion of economic growth, which has generated the need to formulate policies aimed at inclusive development and reducing income inequality. Literature reviews (OECD; Ren et al., 2023; Heshmati, 2019; Lambertini & Proebsting, 2023) identify key inequality factors such as technological change, education systems, globalisation, and labour market reform with relevant institutions. Studies of European countries also show that reductions in government spending have asymmetric effects across sectors, with prices and wages declining mainly in sectors with low exports and products with a low import share. These findings emphasise the importance of coordinated public policies that take structural and institutional frameworks into account and integrate fiscal, educational, trade, and labour-market measures. Successful policies therefore require a comprehensive approach that addresses the root causes of inequality and supports sustainable economic growth.

5. **Future research in the field of working pensioners and the silver economy** should be multidisciplinary, combining economic, social, demographic, and organisational approaches (Cucculelli, 2023; Bojanić, 2024; Krzyminiewska, 2020). Such an approach will enable a comprehensive analysis of the potential of older workers to mitigate labour shortages and support economic growth. At the same time, it will allow for a better understanding of the impact of public policies, age management, and the financial well-being of seniors on their professional activity and standard of living. Multidisciplinary studies can identify optimal strategies for integrating older workers into the labour market and minimise the risks of age discrimination or social inequality. Such research will provide valuable evidence for the design of effective policies and organisational measures in the context of an ageing population.

Slovakia-specific ageing-related challenges and implications for the labour market

Although population ageing is a pan-European trend, Slovakia faces a particularly sharp combination of demographic and labour-market pressures. National demographic projections indicate that population ageing will be one of the most significant structural features of Slovakia's development over the coming decades, alongside population decline, with substantial consequences for labour supply and dependency burdens. In addition, evidence from OECD research shows that Slovakia is expected to age rapidly and that the age of labour-market exit is among the lowest across OECD countries, which increases the urgency of extending healthy working lives and strengthening retention of older workers.

In practical labour-market terms, this creates several interconnected challenges: (1) tightening labour supply and skills shortages as large cohorts retire, (2) heightened pressure on public finances and social protection systems as dependency ratios rise, and (3) increased risk of labour-market segmentation among older workers (e.g., early exit pathways, limited access to reskilling, and age-related discrimination). These pressures reinforce the need to treat the silver economy not only as a consumer-market concept, but also as a strategic labour-market and HRM framework in Slovakia – centred on age management, lifelong learning, and intergenerational knowledge transfer. This is consistent with the paper's argument that Slovakia's demographic change can be converted into economic and organisational value if institutions and employers implement coordinated measures supporting longer working lives and age-inclusive work environments.

Conclusion

The silver economy is emerging as a key pillar of the future labour market and economic policy of the Slovak Republic. Its development requires coordinated cooperation between the state, the business sector, and educational institutions, as well as a change in societal discourse on the value of work and age. If population

ageing is perceived not as a problem but as an opportunity, Slovakia can transform its demographic challenges into economic and social capital, thereby becoming an active participant in the European longevity economy.

From Slovakia's perspective, the findings are of particular significance. According to Eurostat forecasts (2023), the country ranks among the states with the fastest rate of population ageing in Europe, with the share of people aged over 65 potentially exceeding 30% by 2050. This trend represents a major challenge for the sustainability of the workforce, the social system, and public finances, but at the same time offers an opportunity to strengthen innovation potential through an active employment policy for older workers.

Based on the synthesis of scientific knowledge, several recommendations can be formulated for the Slovak labour market and public policy-making:

1. **Development of active ageing policies –** systematic incorporation of the principles of active ageing and lifelong learning into national employment and education strategies.
2. **Support for age management in enterprises –** implementation of age diversity management tools, intergenerational mentoring programmes, and adaptation of the working environment for older workers; the introduction or expansion of part-time work, remote work, and flexible working arrangements that allow older workers to remain active in the labour market according to their abilities and lifestyles.
3. **Reduction of age discrimination –** legislative and awareness-raising measures that promote equal opportunities and improve societal perceptions of older people.
4. **Linking economic and social policy** – integration of employment programmes, healthcare, and social services into a unified longevity policy framework.
5. **Support for research and innovation in the silver economy –** creation of partnerships between academia, public institutions, and businesses with the aim of developing new markets, products, and services for the older population.
6. **Financial and tax incentives –** creation of incentives for companies and individuals to support the employment of older workers, such as tax reliefs and bonuses for intergenerational mentoring.
7. **Policy monitoring and evaluation –** systematic monitoring of the effectiveness of active ageing and age management policies through indicators of employment, employee satisfaction, and economic impact, in order to adapt measures to the real needs of the labour market.

From a theoretical perspective, the article contributes to the development of knowledge by systematising scientific schools and conceptual approaches to the silver economy and by creating a review framework suitable for further research in the Central European context. Its practical contribution lies in the identification of specific areas in which enterprises, state institutions, and the academic community can respond to demographic change proactively, rather than merely adaptively.

From a methodological perspective, the paper confirms that a systematic literature review represents an effective tool for integrating theoretical knowledge across disciplines and that an interdisciplinary approach is essential for a comprehensive understanding of the phenomenon of ageing.

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ORGANISATIONAL FACTORS INFLUENCING WORK-LIFE BALANCE IN THE CONTEXT OF GENERATIONS X, Y AND Z

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Abstract
This article investigates generational differences in work–life balance and examines the influence of organizational factors on its dimensions among employees in Lithuania. Drawing on generational theory and work–life balance research, the study focuses on Generations X, Y, and Z and analyzes how workload, organizational support, flexibility in work location and time, and autonomy relate to employees' perceptions of work-life balance. A quantitative research design was employed using an online questionnaire survey. The final sample consisted of 454 respondents representing Generations X (35.9%), Y (39.2%), and Z (24.9%). Data were analyzed using descriptive statistics, reliability analysis, one-way ANOVA with Tukey HSD post hoc tests, and regression analysis. The results revealed significant generational differences across most organizational factors and all examined work-life balance dimensions. No significant differences were found in perceived workload. Generation X reported significantly higher levels of negative work-to-life and life-to-work interference and lower levels of positive mutual enrichment compared to Generations Y and Z. Significant differences were also observed in perceived organizational support, flexibility, and autonomy, with moderate to large effect sizes. However, regression analyses conducted separately for each generation did not reveal statistically significant relationships between organizational factors and work-life balance dimensions. The findings highlight the importance of adopting differentiated management approaches that consider generational diversity. Organizations should develop adaptive human resource strategies that balance structural stability with flexibility and support employee well-being across generational groups. The study contributes to the understanding of generational dynamics in work–life balance and provides practical implications for sustainable human resources management.
KEY WORDS: work-life balance; generations; management; business organizations, working efficiency.
JEL classification: M14, M54, D79

Introduction

Work-life balance issues are becoming increasingly relevant in contemporary society. The accelerating pace of life, rising workload, rapid technological advancement, and evolving employee expectations create complex situations that directly affect individuals' psychological and physical well-being. These factors not only challenge individuals but also influence organizations and broader economic development.

Although technological progress has introduced greater flexibility in the workplace, it has simultaneously enabled constant connectivity to work, making it increasingly difficult to separate professional and personal life (Wood et al., 2020). Employees often feel obliged to remain available around the clock, which over time may lead to burnout, reduced productivity, and diminished quality of life. This challenge has become particularly evident in the context of remote work, where the boundaries between work and personal life tend to blur.

A growing body of research indicates that work-life imbalance is one of the primary predictors of burnout, which results from prolonged stress and manifests as emotional, physical, and psychological exhaustion (Galanti et al., 2021). Burnout may be expressed through decreased motivation, emotional exhaustion, cynicism, and even serious health problems. The COVID-19 pandemic further intensified work-life balance challenges, as remote work practices, while offering flexibility, also weakened employees' ability to detach from work responsibilities and maintain balance (Galanti et al., 2021).

Work-life balance concerns are further complicated by the presence of multiple generations in today's labour market, each characterized by distinct attitudes toward work, life values, and expectations. Employees from Generations X, Y, and Z encounter different challenges in integrating work and personal life, and these generational differences may shape the factors that most strongly influence work-life balance (Schroth, 2019).

Work-life balance is therefore not solely an individual concern but also an organizational responsibility. Organizations that fail to address these issues often face higher employee turnover, lower engagement, and poorer performance outcomes (Holland et al., 2019). Consequently, organizations seeking to retain productive and loyal employees must consider their needs and establish working conditions that support work-life balance (Lee & Choi, 2019).

Taken together, these considerations demonstrate that work-life balance is not merely a personal challenge but a strategic issue requiring attention at both organizational and societal levels. Only through systematic changes and by acknowledging generational differences can long-term positive outcomes for employee well-being and organizational success be achieved.

Literature review

Different Generations of Employees and Their Characteristics. The contemporary labour market is

characterised by unprecedented generational diversity. For the first time in history, up to four generations are simultaneously active within organisations, creating a complex environment shaped by different values, attitudes towards work, and expectations of loyalty and career development (Lyons & Kuron, 2014). Rapid socio-economic change, technological advancement, and globalisation have intensified these differences and challenged traditional human resource management approaches (Leelamanothum et al., 2018).

Although the concept of generations has existed since the 19th century, it became systematically analysed in the 20th century. Mannheim (1952) conceptualised a generation as a group shaped by shared historical and cultural experiences, while Howe and Strauss (1991) defined it as a birth cohort influenced by similar events and collective values. Later scholars emphasised cultural habitus (Bourdieu, 1984), technological and psychological shifts (Twenge, 2017), and transformations in traditions and social norms (Mead, 1970). Despite broad agreement that a generation consists of individuals born within a similar time frame, there is no universally accepted classification of generational boundaries. This article follows the typology proposed by Howe and Strauss (1991) and focuses on Generations X, Y, and Z, which currently constitute the largest share of the active workforce.

Generation X. Generation X (1961–1981) developed during a period of economic competition and technological change. Often described as independent, pragmatic, and adaptable, members of this generation value autonomy, competence, and results (Coupland, 1991). They seek stability but are cautious about long-term attachment to a single organisation. Work–life balance is important to them, yet they maintain a strong results orientation and belief that hard work leads to success (Palumbo, 2020; Stanišauskienė, 2015).

Their strengths include flexibility, entrepreneurship, and continuous learning. However, a strong focus on performance and external evaluation may increase stress levels and contribute to burnout, particularly when organisational expectations are unclear or support is insufficient (Schmidt et al., 2020). While Generation X employees value managerial trust and decision-making autonomy, insufficient recognition or unmet financial expectations may reduce motivation and increase frustration (Schwartz et al., 2019).

With regard to workload, an important insight emerges. Generation X employees typically began their professional careers in the 1990s or early 2000s, a period marked by more hierarchical, less flexible work cultures that placed limited emphasis on psychological well-being. It is therefore not surprising that members of this generation may be more resilient or less reactive to factors such as workload, autonomy, and flexibility of working time and location. For them, workload may not necessarily signify stress, but rather meaning, responsibility, or even professional status. In other words, what is theoretically framed as a risk factor may, in their lived experience, be interpreted as a positive indicator – for example, being assigned many tasks may signal that one is valued and needed.

Generation Y. Generation Y (1982–2002), also known as Millennials, grew up during globalisation and the rapid expansion of digital technologies. They are characterised by optimism, global thinking, and a strong orientation towards meaning and self-realisation (Twenge, 2017). For this generation, work must be meaningful and aligned with personal values. They prioritise flexibility, work-life balance, and emotional well-being (Lyons, 2004; Leelamanothum et al., 2018).

Generation Y employees value feedback, mentorship, and opportunities for development. Organisations that provide socially responsible and value-driven environments are more successful in attracting and retaining them (Mahmoud et al., 2021). At the same time, high expectations, desire for rapid recognition, and resistance to rigid hierarchies may create tension within traditional organisational structures (Alkire et al., 2020; Rohrich & Rodriguez, 2020)

While flexibility and emphasis on personal well-being may protect against burnout, blurred boundaries between work and personal life, combined with unmet expectations of meaning, can increase emotional exhaustion (Kossek et al., 2012). Thus, effective management of Generation Y requires balancing autonomy with clear structures and consistent feedback systems.

Generation Z. Generation Z (2003 onwards) represents the first fully digital generation. Their worldview and professional expectations are strongly shaped by technological immersion and global interconnectedness (McCrindle & Fell, 2019). They demonstrate exceptional digital competence, adaptability, and openness to diversity (Stillman & Stillman, 2018).

This generation values transparency, clearly defined roles, continuous learning, and opportunities for rapid professional growth (Barhate & Dirani, 2022; Seemiller & Grace, 2018). Social responsibility and organisational impact are important factors influencing their engagement. Recognition and flexibility are essential motivational drivers.

However, constant connectivity and ambition for rapid advancement may increase vulnerability to stress and burnout (Twenge, 2017; Zahra & Hermiati, 2023). Unrealistic career expectations and excessive self-confidence may also generate dissatisfaction and emotional strain (Schmitt & Lancaster, 2019). Therefore, organisations must support Generation Z by promoting healthy boundary management, realistic goal-setting, and sustainable workload distribution.

Generational differences significantly influence work values, motivational drivers, and vulnerability to burnout. Generation X prioritises stability, autonomy, and material recognition, yet may experience stress due to strong performance orientation. Generation Y seeks meaningful, flexible, and value-aligned work but may struggle when expectations are unmet. Generation Z values innovation, inclusivity, and rapid development, yet faces risks associated with constant connectivity and accelerated career aspirations.

These differences demonstrate that universal human resource management practices are no longer sufficient. Organisations must adopt differentiated and adaptive strategies that combine structural stability with flexibility, technological integration with psychological support, and

performance orientation with employee well-being. Only by recognising and integrating generational diversity can organisations transform potential tensions into sustainable competitive advantage.

Work-life balance and Analysis of Influencing Factors

Work-life imbalance arises when professional and personal commitments are incompatible, making it difficult to fulfil one obligation while carrying out the other (Chen & Fulmer, 2018). Imbalance most commonly manifests through a lack of time, energy, and psychological resources, when work tasks begin to interfere with personal life or vice versa (Wood et al., 2020). Research shows that long-term work-life imbalance may lead to negative consequences, including emotional exhaustion, job dissatisfaction, and reduced productivity (Eddleston & Mulki, 2017). Conflict emerges precisely from the inability to find equilibrium between these two domains; therefore, it is essential to analyse and understand how balance can be restored and how long-term negative effects on both employees and organisations can be prevented.

The work-life balance phenomenon has been widely examined in academic research, with numerous studies and ongoing discussions addressing its importance and consequences in scholarly literature as well as in public discourse (Sirgy & Lee, 2018). The term work-life balance was first used in 1986 in the United States (Lockwood, 2003). The issue became particularly significant during the 1980s, when women increasingly entered the labour market while continuing to carry primary household responsibilities (Jain & Rawat, 2021). In academic literature, the concept of work-life balance has evolved: initially understood as harmony between work and family, it is now recognised as a broader construct acknowledging that individuals perform multiple roles in both personal and professional life beyond family responsibilities (Poulose & Sudarsan, 2017).

There is no single universally accepted definition of work-life balance in academic literature. Various scholars define the concept differently (Table 1).

Table 1. Definition of Work-Life Balance

Author	Definition of Work-Life Balance
Clark (2000)	Work-life balance is the satisfactory distribution of time and attention between work and family needs.
Friedman & Greenhaus (2000)	Work-life balance is an integrated approach that enables an individual to successfully manage multiple life domains.
Kalliath & Brough (2008)	Work-life balance is individuals' perception that they effectively manage work and personal life according to their priorities.
Guest (2002)	Work-life balance is the subjective level of satisfaction an individual experiences when managing work and personal life demands.
Kossek & Ozeki (1998)	Work-life balance is harmony between work and family commitments, allowing conflicts between these domains to be reduced.
Hill (2005)	Work-life balance is an individual's ability to integrate work obligations and personal needs in a way that benefits both domains.

In summary of the definitions presented in Table 1, work-life balance can be understood as the compatibility of an individual's roles, ensuring that each role is equally satisfying and performed with comparable effectiveness. In other words, work-life balance is associated with overall harmony in life.

Academic literature distinguishes three components of work-life balance identified by Greenhaus et al. (2003). The first, time balance, refers to allocating equal time to both work and family roles. The second, involvement balance, denotes equal psychological engagement in work and family domains. The third component, satisfaction balance, reflects equal levels of satisfaction derived from both work and family roles.

Each component time, involvement, and satisfaction may be either balanced or imbalanced depending on whether their levels are comparable (Greenhaus et al., 2003). Harmony among these three elements reduces problems related to work, family, and stress (Palumbo, 2020). Research has shown that time and involvement balance have the strongest impact on overall quality of life. When individuals fail to align these components due to time constraints, low engagement, or dissatisfaction, they often experience work-life imbalance, which negatively affects roles in both the workplace and personal life (Greenhaus et al., 2003).

Studies further indicate that individuals who successfully balance work and personal life experience significantly less stress, as they are able to devote sufficient attention to all important life domains (Greenhaus et al., 2003). Moreover, balance has been found to contribute to employee growth and personal well-being (Palumbo, 2020). In contrast, work-life imbalance may lead to health problems, family difficulties, and reduced work quality (Vyas, 2022; Wood et al., 2020).

Scientific literature sources identifies numerous factors influencing an individual's work-life balance. Increasing attention is given to this issue, which is considered not only an individual responsibility but also an organisational one. The more satisfied individuals are with their working conditions and the better they can integrate professional and personal life, the more productive and effective they become at work.

Modern employees frequently encounter stress, tension, and multiple responsibilities, which often challenge the maintenance of work-life balance. For this reason, organisational leaders and human resource professionals must collaborate to create favourable conditions and a positive work environment focused not only on economic and social aspects but also on employee well-being.

Researchers identify several key organisational factors that significantly influence work-life balance: organisational support (Sirgy & Lee, 2017; Kumpikaitė-Valiūnienė et al., 2021; Kurtessis et al., 2017), workload (Putri & Amran, 2021; Ramakrishnan, 2020) flexibility of working time and location (Irawanto et al., 2021; Vander, 2024), and autonomy (Sia & Appu, 2015; Bakker & Demerouti, 2014; Zhang & He, 2022; Kossek & Ozeki, 1998). These factors are shaped and maintained by the organisation and are not directly chosen by the employee.

Organisational support refers to employees' perception that the organisation values their contribution and cares

about their well-being (Sirgy & Lee, 2017). Support is ensured through clear communication, motivation systems, work planning, and other structured mechanisms (Šorytė & Pajarskienė, 2014). Employees benefit from feeling supported and understood, as support enhances self-confidence, motivation, and satisfaction with work outcomes (Grincevičienė, 2020). Employees who experience professional satisfaction can devote more attention to their personal lives, thereby maintaining work-life balance (Sirgy & Lee, 2017).

Employees who perceive organisational support are more likely to maintain work-life balance than those who do not (Kumpikaitė-Valiūnienė et al., 2021). Organisational support benefits both employees and organisations by strengthening organisational commitment and motivating individuals to contribute to organisational goals (Kurtessis et al., 2017, Shevchyk, 2025). The idea that employee commitment depends on perceived organisational commitment to them is also supported by Eisenberger et al. (1986).

Rhoades and Eisenberger (2002) distinguish three primary features of organisational support: supervisor support and fairness; organisational rewards; favourable working conditions. Fairness is particularly important, as individuals are motivated by perceptions of justice in social relationships (Petrauskienė & Kubričenkaitė, 2023). Achieving balance between employee input and outcomes fosters strong and productive relationships. These factors enhance employees' sense of value and strengthen interpersonal relationships within organisations.

Organisational support may also be reflected in supportive practices such as flexible working hours, childcare assistance, parental and caregiving leave, wellness programs, family leave policies, social support at work, seminars, and training (Sirgy & Lee, 2017). Such measures help restore work-life balance, promote employee loyalty and commitment, and support retention.

Organisations increasingly adopt family-friendly policies and work-life balancing initiatives that ensure mutual satisfaction and demonstrate genuine commitment beyond formal declarations (Kurtessis et al., 2017). Employees must feel managerial support and confidence in using these opportunities (Utomo et al., 2023).

Changes in employer attitudes and efforts to create supportive work environments reflect recognition that work-life balance positively affects not only employee well-being but also organisational performance and talent retention (Ko, 2024).

Traditionally, work-life balance challenges have been more frequently associated with women, as they have been viewed as primary caregivers, while men have often been perceived as primarily responsible for financial stability and career advancement (Thompson et al., 2020). However, given that individual priorities differ, balance initiatives should not be based solely on gender. Family-friendly organisational policies enable both men and women to combine family formation and child-rearing with professional activity (Utomo et al., 2023).

The environment in which individuals spend most of their day significantly influences their well-being during and after work. Therefore, it is crucial that employees feel safe, understood, and supported. Organisational support strengthens managerial–employee relationships and enhances motivation and commitment.

Work flexibility is often divided into time and location flexibility, allowing employees to schedule working hours and choose where they work (Irawanto et al., 2021). Today, this is commonly referred to as remote work. By offering remote work options, employers help employees better integrate work and personal life (Putri & Amran, 2021). Remote employees often report increased flexibility, productivity, and time savings (Ramakrishnan, 2020). Remote work is linked to employee well-being, health, and reduced work-life conflict (Putri & Amran, 2021). However, it may also blur boundaries between work and rest, reduce social interaction, and create challenges related to privacy and digital competencies (Vander, 2024).

Excessive workload occurs when employees are required to complete numerous tasks within limited timeframes, adhere to strict deadlines, and work rapidly, negatively affecting well-being and job satisfaction (Putri & Amran, 2021). Extended working hours increase workload and hinder work-life balance (Ramakrishnan, 2020). Heavy workload may contribute to stress, sleep disturbances, and mental health risks, as well as physical symptoms such as headaches and psychological symptoms such as anxiety and insomnia (Guest, 2002).

Workplace autonomy, defined as employees' ability to make independent decisions, significantly supports work-family balance and reduces inter-role conflict (Clark, 2000). Employees who regulate their own schedules and tasks report higher satisfaction in both personal and professional domains (Sia & Appu, 2015). Autonomy reduces stress, enhances psychological health, and fosters motivation and organisational loyalty (Bakker & Demerouti, 2014). It also decreases burnout risk and improves productivity and work quality (Zhang & He, 2022; Kossek & Ozeki, 1998).

By combining the insights provided by different authors, four elements can be distinguished that have a key influence on the restructuring of the organizational structure of companies. Its restructuring responds to the needs of work-life balance in relation to employees. It is necessary to emphasize that integrated solutions are needed that respond to different generations of employees. In the case of some employees, the fact that opportunities have been created to create a more flexible work schedule is sufficient. However, in other cases, additional internal communication is necessary with those employees who are not familiar with the opportunities created for them. This is important so that representatives of different generations understand that this is a measure focused on the well-being of employees, and not on the redistribution of certain work functions.

In conclusion, work-life balance is a complex phenomenon influenced by multiple interrelated factors and should therefore be approached holistically. Instead of focusing solely on generational categories, future studies could examine individuals according to life cycle stages – for example, parental status, marital status, career stage, or proximity to retirement. This perspective may offer a more context-sensitive understanding and move beyond potentially overgeneralized generational explanations.

Finally, incorporating psychological variables – such as emotional resilience, value orientations, and intrinsic motivation – into future research may provide deeper insight into work-life balance experiences. These internal factors may play a more substantial role than organizational aspects in explaining how individuals navigate the relationship between work and personal life.

Methodology

The research employed a quantitative research design using an online questionnaire survey to collect data from respondents across different generational cohorts. The research instrument incorporated previously validated scales measuring work–life balance dimensions and organizational factors (see Table 2 for details on sources, number of items, and scale characteristics). All items were assessed using a 7-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree").

Participants were recruited using a non-probability convenience sampling method. Therefore, the findings should be interpreted with caution, as they cannot be generalized to the entire population. Data were collected in Lithuania, yielding 454 fully completed questionnaires, exceeding the minimum required sample size of 399 respondents. Participation was voluntary and anonymous, and informed consent was obtained prior to survey completion in accordance with institutional ethical standards.

Statistical analyses were conducted using IBM SPSS Statistics 27.0. The analysis included descriptive statistics, reliability analysis, ANOVA, correlation analysis, and regression analysis.

The research aimed to examine generational differences in work–life balance dimensions and to evaluate the influence of organizational factors on these dimensions. Generational differences were tested using one-way ANOVA, followed by Tukey HSD post hoc comparisons (Table 3).

Table 2. Research instrument

Variable		Scale and author	Number of statements
Work-life balance	Negative impact of work on personal life	Hayman (2005) Work-Life Balance Scale	7
	Negative impact of personal life on work		4
	Positive mutual impact of work and personal life		4
Workload		Copenhagen Psychosocial Questionnaire (2005) Workload Subscale	4
Organizational support		Copenhagen Psychosocial Questionnaire (2005) Supervisor and Coworker Support Subscales	6
Flexibility in work location and time		Hill et al. (2001)	4
Autonomy		Morgeson & Humphrey (2006) Work Design Questionnaire, Autonomy Subscale	3

Table 3. ANOVA test

Dependent variable	F (2, 451)	p	η^2
Workload	1.84	.160	.008
Organizational support	14.92	< .001	.062
Flexibility in work location and time	48.67	< .001	.110
Autonomy	79.54	< .001	.121
Negative impact of work on personal life	36.21	< .001	.138
Negative impact of personal life on work	28.47	< .001	.112
Positive mutual impact of work and personal life	54.83	< .001	.135

A one-way ANOVA was conducted to examine generational differences in organizational factors and work–life balance dimensions (see Table 3). The analysis revealed no statistically significant differences between generations in perceived workload, $F(2, 451) = 1.84$, $p = .160$, $\eta^2 = .008$, indicating a negligible effect size.

However, statistically significant generational differences were found in organizational support, $F(2, 451) = 14.92$, $p < .001$, $\eta^2 = .062$, reflecting a medium effect size. Substantial differences were also observed in flexibility in work location and time, $F(2, 451) = 48.67$, $p < .001$, $\eta^2 = .110$, and autonomy, $F(2, 451) = 79.54$, $p < .001$, $\eta^2 = .121$, both indicating large effect sizes.

Significant generational differences were further identified across all examined work–life balance dimensions. The negative impact of work on personal life differed significantly between generations, $F(2, 451) = 36.21$, $p < .001$, $\eta^2 = .138$, as did the negative impact of personal life on work, $F(2, 451) = 28.47$, $p < .001$, $\eta^2 = .112$. Additionally, the positive mutual impact of work and personal life demonstrated significant differences, $F(2, 451) = 54.83$, $p < .001$, $\eta^2 = .135$. These findings indicate

moderate to large generational effects in work–life balance perceptions.

Post hoc comparisons using Tukey HSD indicated that Generation X differed significantly from Generations Y and Z in organizational support, flexibility, autonomy, and positive mutual impact of work and personal life ($p < .005$). In these cases, Generation X reported consistently lower evaluations compared to the younger generations, while no statistically significant differences were observed between Generations Y and Z.

For the negative impact of work on personal life and the negative impact of personal life on work, significant differences were observed across all three generations, indicating a clear generational gradient in work–life balance perceptions. Detailed pairwise comparisons are presented in Appendix A.

Reliability testing confirmed satisfactory internal consistency of all scales. Cronbach's alpha coefficients ranged from 0.866 to 0.943 in the overall sample. Reliability was also examined separately across generational groups (Table 4), with coefficients demonstrating acceptable to high internal consistency in Generation X ($\alpha = 0.862–0.941$), Generation Y ($\alpha = 0.867–0.945$), and Generation Z ($\alpha = 0.866–0.941$).

Table 4. Cronbach's alpha

Variable		Main Cronbach's alpha	Generation X Cronbach's alpha	Generation Y Cronbach's alpha	Generation Z Cronbach's alpha
Work-life balance	Negative impact of work on personal life	0.943	0.941	0.945	0.941
	Negative impact of personal life on work	0.911	0.910	0.911	0.913
	Positive mutual impact of work and personal life	0.866	0.862	0.867	0.866
Workload		0.889	0.886	0.891	0.888
Organizational support		0.901	0.903	0.901	0.900
Flexibility in work location and time		0.882	0.880	0.882	0.882
Autonomy		0.925	0.922	0.926	0.926

As presented in Table 4, all constructs demonstrated high internal consistency across generational groups. Cronbach's alpha coefficients exceeded the recommended threshold of 0.70 in all cases. The similarity of reliability coefficients across Generation X, Y, and Z suggests measurement stability of the constructs within the analyzed sample.

Results and discussion

The research examining organizational factors influencing work–life balance among employees from different generations included 454 respondents representing Generation X (35.9 %), Generation Y (39.2 %), and Generation Z (24.9 %).

The analysis of the ANOVA test results revealed that Generation X experiences significantly higher levels of both negative work-to-life interference and negative life-to-work interference compared to Generations Y and Z. In contrast, Generations Y and Z report significantly higher levels than Generation X in terms of perceiving positive mutual enrichment between work and personal life. It is also important to note that no statistically significant differences were found between Generations Y and Z.

In this research, an additional objective was to determine the manifestation of work–life balance among employees from different generations who participated in the research. Therefore, means and standard deviations were calculated (Table 5).

Table 5. Means and standard deviations of work-life balance dimensions

Dimension	Mean			Standard deviation		
	Generation X	Generation Y	Generation Z	Generation X	Generation Y	Generation Z
Negative impact of work on personal life	5.21	3.92	3.64	1.07	1.26	1.29
Negative impact of personal life on work	3.62	2.55	2.30	2.11	1.24	1.10
Positive mutual impact of work and personal life	2.63	4.31	4.56	1.39	1.21	1.28

When analysing the negative impact of work on personal life, the strongest effect was observed among Generation X employees ($M = 5.21$). A considerably lower mean was found in Generation Y ($M = 3.92$), while the lowest mean was recorded among Generation Z representatives ($M = 3.64$). A similar pattern emerged when assessing the negative impact of personal life on work. The highest mean was identified in Generation X ($M = 3.62$), whereas lower means were observed in Generation Y ($M = 2.55$) and Generation Z ($M = 2.30$).

In contrast, positive work-life interaction was evaluated most highly by Generation Z employees ($M = 4.56$), followed by Generation Y ($M = 4.31$). The lowest

evaluation of this dimension was reported by Generation X (M = 2.63).

To determine the influence of organizational factors on employees' work-life balance, regression analyses were conducted separately for Generations X, Y, and Z. The results indicated that, across all three generational groups, no statistically significant relationships were found between work-life balance dimensions and organizational factors.

As shown in Table 6, no significant relationships were found between organizational factors and work-life balance among Generation X employees. Organizational factors very strongly explain the negative impact of work on personal life (64%) and the positive work-life interaction (63%).

Table 6. Regression analysis of Generation X organizational factors and work-life balance dimensions

Organizational factors	**Negative impact of work on personal life**	**Negative impact of personal life on work**	**Positive mutual impact of work and personal life**
	$R^2 = 0.641$ $p = 0.000$	$R^2 = 0.125$ $p = 0.013$	$R^2 = 0.634$ $p = 0.000$
Workload	0.045	0.284	-0.313
Organizational support	-0.458	-0.565	0.452
Flexibility in work location and time	-0.594	-0.283	0.101
Autonomy	-0.511	-0.310	0.630

Table 7 illustrates similar results for Generation Y, where none of the predictors reached statistical significance. It can be argued that workload worsens the entire work-life balance in the case of Generation Y. Organizational support, flexibility, and autonomy reduce the likelihood of potential conflicts. Flexibility and organizational support most strongly strengthen the positive interaction between work and personal life.

Table 7. Regression analysis of Generation Y organizational factors and work-life balance dimensions

Organizational factors	**Negative impact of work on personal life**	**Negative impact of personal life on work**	**Positive mutual impact of work and personal life**
	$R^2 = 0.068$ $p = 0.008$	$R^2 = 0.136$ $p = 0.000$	$R^2 = 0.153$ $p = 0.000$
Workload	0.211	0.132	-0.069
Organizational support	-0.002	-0.652	0.271
Flexibility in work location and time	-0.252	-0.985	0.460
Autonomy	-0.126	-0.856	0.116

Regression analysis of Generation Z employees revealed that organizational factors also did not show statistically significant influences in this generation (see Table 8). The first two models are statistically non-significant – therefore, it cannot be firmly stated that organizational factors predict negative aspects in the future. The third model is significant – organizational factors reliably promote positive work-life interaction. Flexibility is especially important for this generation – increasing it can lead to positive performance outcomes.

Table 8. Regression analysis of Generation Z organizational factors and work-life balance dimensions

Organizational factors	**Negative impact of work on personal life**	**Negative impact of personal life on work**	**Positive mutual impact of work and personal life**
	$R^2 = 0.331$ $p = 0.654$	$R^2 = 0.208$ $p = 0.114$	$R^2 = 0.160$ $p = 0.000$
Workload	0.045	0.452	-0.616
Organizational support	-0.628	-0.806	0.342
Flexibility in work location and time	-1.017	-1.258	0.864
Autonomy	-0.762	-1.189	0.361

The absence of statistically significant effects of organizational factors within this generation may indicate that Generation Z's attitudes toward work, stress, and work-life balance are still evolving, given their relatively limited professional experience. Members of this generation often hold multiple jobs simultaneously, are highly socially engaged, and seek rapid outcomes; however, they may also display lower levels of long-term commitment or patience (McCrindle & Fell, 2019; Stillman & Stillman, 2018).

Workload may be experienced differently. Generation Z tends to accept the fast-paced intensity characteristic of

contemporary work culture more readily, while at the same time demonstrating greater awareness of psychological health, personal boundaries, and self-care (Barhate & Dirani, 2022). High workload may be perceived as a natural life phase; however, when stress or discomfort becomes excessive, members of this generation are more likely to change environments, withdraw from the situation, or fundamentally reassess their relationship with work. Such adaptive flexibility may help explain the absence of statistically significant relationships between organizational factors and work-life balance dimensions, as individuals may proactively alter unfavorable circumstances rather than remain within them. However, some studies suggest that generational differences may be small or not sufficiently substantiated (Rudolph et al, 2020). In particular, little emphasis is given to generational differences in the workplace, indicating the need to improve the organizational structure (Costanza, Finkelstein, 2015). This study showed that generational differences are most visible in the aspect of communication - one generation emphasizes the opportunity to work, while others - the pursuit of autonomy and work appreciation. This is directly related to generational differences, and consistent communication between managers is necessary to reduce tension at work.

The research showed that clear extremes are visible when comparing the oldest and youngest generations. This factor will create significant challenges for organizations related to balancing different interests, strengthening organizational culture, and responding to problematic situations. Taking into account the needs of employees of different generations would allow for the creation of dedicated incentive and employee welfare programs that would meet the needs of the organization's employees.

Conclusions

Existing fundamental differences will significantly affect the work of future organizations and the formation of teams. When changing the organization's employees and not changing the work culture, companies risk experiencing significant negative impacts both in the tactical and strategic periods. Not taking into account the needs of employees representing the youngest generations creates negative reputational consequences for the organization, which may require significant time and marketing resources to eliminate. Reviewing internal procedures, strengthening internal communication, and creating clear measures that meet the needs of employees will make it easier to adapt to the changing needs of employees. At the same time, this will create conditions for strengthening the organization and increasing the level of reputation.

Adapting to the specifics of different generations requires integrated and consistent solutions applied in the long term. This also includes changes in organizational values, which require strong and clear support from management. The lack of systematized knowledge about organizational changes from a generational perspective will encourage future quantitative research related to identifying key risks and priority solutions.

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MINDFULNESS AND FINANCIAL BEHAVIOUR AMONG STUDENTS: THE ROLE OF FINANCIAL SELF-EFFICACY AND GENDER

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Abstract
Students' financial behaviour is a factor influencing not only their academic success and psychological well-being but also their long-term socioeconomic stability, making it essential to understand the psychological mechanisms that shape responsible money management. Since formal financial knowledge alone does not automatically lead to better financial behaviour, financial education initiatives need to be enhanced. It is beneficial to incorporate components into interventions that purposefully strengthen not only practical skills but also psychological resources - namely, students' self-regulatory capacities and financial confidence. Mindfulness, which enhances awareness and self-regulation, together with financial self-efficacy, which reflects confidence in managing financial tasks, may jointly shape students' financial behaviour. The aim of the study was to investigate whether the relationship between mindfulness and financial behaviour in college students is mediated by financial self-efficacy and whether this indirect effect differs by gender. The sample of the study was 708 students (594 females, 114 males) from the College of Business Administration (Latvia) enrolled in short-cycle higher professional education programmes. Quantitative data were collected through a survey encompassing scales for measuring financial behaviour (shortened OECD INFE Financial Behaviour measure), mindfulness (Cognitive and Affective Mindfulness Scale – Revised, by Feldman et al., 2006), and financial self-efficacy (Financial self-efficacy scale by Loke & Choi, 2015). Mediation analysis with 5,000 bootstrap samples revealed that financial self-efficacy statistically mediated the association between mindfulness and financial behaviour ($B = 0.27$, 95% CI [0.18, 0.38]), indicating partial mediation. Moderated mediation analysis showed no gender differences in the indirect effect of mindfulness on financial behaviour via financial self-efficacy (Index = −0.01, 95% CI [−0.27, 0.21]). There were no gender differences in measures of mindfulness, financial behaviour and financial self-efficacy. Findings highlight the potential importance of mindfulness and financial self-efficacy in promoting responsible financial behaviour among students of both genders, as well as the underlying pathways through which these factors may operate. The results suggest that interventions aiming to foster sustainable financial behaviour may benefit from incorporating components that strengthen self-regulatory capacities and financial confidence, highlighting the need for further research to deepen understanding of these relationships and their practical implications.
KEY WORDS: financial behaviour, mindfulness, financial self-efficacy, college students, gender differences, mediation analysis, moderated mediation.
JEL Classification: D14, D91, I23, J16

Introduction

Sustainable economic outcomes depend on individuals' ability to make responsible financial decisions, which are closely linked to sound financial behaviour. Financial behaviour is directly linked to financial well-being as a significant element influencing the welfare of individuals, households, societies, and nations on a global scale (Rahman et al., 2021), and it is shaped not only by objective economic factors but also by subjective psychological factors. Therefore, research on financial behaviour should consider both economic and psychological determinants in order to better understand how individuals make financial decisions. In this context, increasing attention has been paid studies suggesting that psychological factors may play both mediating and moderating roles in financial decision-making, including mindfulness, and financial self-efficacy (Riaz et al., 2022). While such studies provide valuable insights into the psychological factors related to financial literacy, less is known about how these factors shape actual financial behaviour, highlighting the need for further research in this area.

Mindfulness has recently attracted attention in research on financial decision-making. It represents individual's awareness of present experiences and capacity for self-regulation, which can support more deliberate and responsible decisions (Garad, 2024). Mindfulness may contribute to prudent financial behaviour and improved financial well-being (Rydzik, 2016; Smith et al., 2016). However, less is known about the pathways through which mindfulness may influence financial behaviour. Prior studies have primarily examined direct relationships between mindfulness and financial behaviour (Rydzik, 2016; Smith et al., 2016), or the role of financial self-efficacy as an independent predictor of financial outcomes (Farrell et al., 2016; Olajide et al., 2025). However, empirical evidence on how mindfulness relates to financial behaviour, particularly through financial self-efficacy, is limited, and little is known about gender differences, especially among college students in Central and Eastern Europe.

One potential pathway is financial self-efficacy, defined as an individual's confidence in managing financial responsibilities (Farrell et al., 2016). Higher financial self-efficacy has been associated with behaviours such as budgeting, saving, and financial planning (Olajide et al., 2025), whereas mindfulness may enhance this confidence by strengthening self-regulation and reflective decision-making, thereby indirectly promoting responsible financial behaviour.

Gender differences have been widely explored in research on financial literacy and its dimensions. While financial decision-making has historically been associated more strongly with men (Damon & Perez, 2024), recent

studies indicate that women are increasingly strengthening their financial knowledge and independence (García-Santillán et al., 2025). Exploring gender differences may therefore help determine whether the psychological mechanisms underlying financial behaviour operate similarly across groups.

Students represent a pivotal segment of society. They are in the process of developing independent financial habits that may affect their long-term financial outcomes. Understanding how mindfulness and financial self-efficacy relate to students' financial behaviour may therefore provide useful insights for developing more effective financial education and intervention programmes. Existing research has not sufficiently examined these constructs within an integrated framework that simultaneously considers the indirect relationship between mindfulness and financial behaviour through financial self-efficacy and potential gender differences in this process. Studies addressing these relationships among college students are scarce, especially in the context of Central and Eastern Europe. Addressing this gap may provide a more comprehensive understanding of the psychological factors underlying students' financial behaviour and support the development of more effective financial education interventions.

Therefore, there is a need to better understand the psychological mechanisms underlying financial behaviour by examining how mindfulness translates into financial outcomes and whether this process differs across individuals. **The aim of the study** is to examine the relationship between mindfulness and financial behaviour among college students by analysing the mediating role of financial self-efficacy and potential gender differences. To achieve this aim, the study pursues the following **research objectives**: 1. to examine the relationship between mindfulness and financial behaviour among college students; 2. to investigate whether financial self-efficacy mediates the relationship between mindfulness and financial behaviour; 3. to assess whether this mediation effect differs across genders; 4. to explore gender differences in mindfulness, financial self-efficacy, and financial behaviour. **Research object** is financial behaviour of college students. **Research subject** is the relationship between mindfulness, financial self-efficacy and students' financial behaviour, including indirect effects and gender differences.

To achieve the purpose of the study, authors employed a quantitative survey design and mediation analysis. Moderated mediation analysis was additionally conducted to explore whether this indirect relationship varies by gender. Details of the analytical approach are presented in the Research Methods section.

The study contributes to understanding of the psychological mechanisms underlying students' financial behaviour through the integration of mindfulness and financial self-efficacy. It provides empirical evidence from the Latvian context and highlights the role of indirect relationships and gender differences. The findings also have practical implications, as they may support the development of more effective financial education and intervention programmes not only for students in higher education, but also for broader population groups across diverse socioeconomic contexts.

Theoretical Background

Financial behaviour. Financial behaviour is a complex concept that characterizes an individual's actions related to money management (Berlinger et al., 2025). This definition encompasses a wide range of activities, including saving, investing, borrowing, and other financial decisions. OECD (2023) states that financial behaviour is an individual's strategic action to safeguard their financial situation in both the short and long term, which is manifested through planning future expenses, choosing financial products, or taking on debt obligations. There are three main domains of financial behaviour: day-to-day management, financial planning, and purchasing complex financial services and products (Sesini et al., 2023).

Saving is an important aspect of financial behaviour that fundamentally affects an individual's long-term financial planning and well-being. Research indicates a statistically significant positive correlation between saving and individual well-being, emphasizing the interaction between cognitive processes and financial behaviour (Choowan et al., 2025). Understanding saving strategies is essential for rational financial planning and achieving long-term goals, which reduces financial uncertainty. In addition, saving fosters an individual's psychological well-being by creating a sense of security and control, which are important components of mental health (Du Plessis et al., 2025). An individual's ability to effectively manage financial resources depends on the application of understanding and knowledge, and comprehension of the principle of saving is critically important for ensuring financial stability and overall well-being.

Akben-Selcuk (2015), in a study conducted among students in Turkey, found that parental involvement during childhood directly impacts later financial actions. This insight can supported by a theoretical framework in which psychological factors (emotions, cognitive biases, self-control, discipline, and financial literacy) intertwine with social and cultural factors (social norms, values, and family habits). These internal and social factors are further complemented by economic and environmental factors (economic conditions, availability of financial services, and legal regulation), which together form a complex mechanism shaping individuals' financial behaviour (Berlinger et al. 2025).

Mindfulness. The concept of mindfulness has been examined across a wide range of work-related contexts (Dhiman, 2021), as well as in terms of its practical applications in business and financial education (Rydzik, 2016; Riaz et al., 2022; Garad, 2024). It is defined as the ability to remain focused on the present moment. It is characterized by the dimensions of attention, acceptance, awareness, and presence, and has a positive effect on cognitive functioning and productivity (Feldman et al., 2006). The main characteristics of mindfulness significant in relation to financial behaviour are intentional awareness of the present moment, non-reactivity and non-judgement of inner experience, observation, acting with awareness, being highly concentrated, focused and enhanced awareness of multiple perspectives in problem-solving, clarity and equilibrium (Garbinsky et al., 2024). Summarized definitions indicate that it is a universal human capacity that can potentially be cultivated through

diverse paths (Dhiman, 2021). Studies reveal barriers to the use of mindfulness: attachment (the drive to gain or unwillingness to let go), aversion (the fear of losing what one has, such as status, material and financial resources), inability to assess what is currently faced, envy and jealousy, and pride (the tendency to compare oneself with others in financial matters) (Adiandari et al., 2024).

Researchers have expanded mindfulness research, moving beyond the effects of mindfulness on physical and mental health to its role in financial health and financial behaviour. The concept of financial mindfulness has been proposed, and two aspects of financial mindfulness are emphasized: having financial awareness and responding with financial acceptance. Financial awareness is the tendency to possess or obtain accurate knowledge of one's present financial state, and financial acceptance is the ability to manage emotions that arise when engaging in financial matters (Garbinsky et al., 2024). In the practical application of mindfulness to financial behaviour, the dual process model is proposed where financial attitudes and financial behaviours are two parallel competitive processes (reflexive and reflective) operating separately towards finances yet ultimately converging to review financial functionality. A higher level of mindfulness may result in a better balance of reflexive and reflective systems which has an effect on an individual's money attitudes and behaviours (Rydzik, 2016). It has been found that financial mindfulness helps the female entrepreneurs to be more rational rather than emotional pertaining to their investment decision-making than male entrepreneurs (Iram et al., 2023). Taken together, the literature suggests that mindfulness may play a significant role in shaping financial behaviour by enhancing awareness of one's financial situation, reducing impulsive and emotionally driven decisions, and supporting more reflective and balanced financial choices.

Financial self-efficacy. Self-efficacy represents people's judgments of their capabilities to accomplish a certain level of performance by organizing and executing courses of action, given past performance and expectations, and it determines how much effort people will use and how long they will persist in the face of obstacles (Bandura, 1986). It is categorized into general and specific self-efficacy, where the latter means people's judgment about their capabilities in the particular domain of functioning (Artino, 2012). Financial self-efficacy is peoples' perceived ability to accomplish financial tasks (Furrebøe & Nyhus, 2022) and can be considered as one of the dimensions of financial literacy. In recent years, self-efficacy has been examined as a factor reflecting individuals' confidence in their financial management abilities, independent of other components of financial literacy (Farrell et al., 2016). Increased financial self-efficacy can enhance financial outcomes and improve resilience when facing challenges (Furrebøe & Nyhus, 2022). Gamst-Klaussen et al. (2019) indicate that people who doubt their abilities to manage financial resources are more likely to reduce their efforts and thus are more susceptible to unfavourable financial behaviours, such as impulse purchases. Thus, financial self-efficacy plays a significant role in shaping financial behaviour, encourages persistence in managing resources, and may reduce susceptibility to impulsive financial decisions.

Financial self-efficacy as a potential mediator between mindfulness and financial behaviour. Analysis of the compiled studies (Rydzik, 2016; Riaz et al., 2022; Garbinsky et al., 2024; Adianandari et al., 2024) shows that financial behaviour is shaped by a variety of variables. Growing attention has turned to the potential role of mindfulness in explaining financial behaviour, however, the link between mindfulness, its practices and personal finances is still insufficiently studied (Adiandari et al., 2024). One possible pathway is financial self-efficacy - confidence in one's ability to manage financial responsibilities (Farrell et al., 2016), since financial behaviour requires high financial self-efficacy (Olajide et al., 2025). Previous studies suggest that mindfulness fosters adaptive money attitudes and self-regulation, which strengthen financial self-efficacy and, in turn, responsible financial behaviour (Palmer et al., 2021; Riaz et al., 2022; Garbinsky et al., 2024). It is argued that general self-regulation is indirectly linked to financial management behaviours through self-efficacy, indicating that combining financial education with mindfulness-based practices may be particularly effective (Palmer et al., 2021; Riaz et al., 2022).

The context of gender differences. Gender differences in characteristics of financial literacy have received constant attention in scientific inquiry. Findings are not conclusive and should be interpreted in light of sociocultural factors. For example, there was no gender gap in financial knowledge and attitudes among undergraduate finance students in Hungary, however, female students were approximately 10% less likely than males to explore highly advantageous financial opportunities, even when other characteristics like psychological traits, attitudes and knowledge were equal (Berlinger et al., 2025). Men, compared to women, more often choose higher-risk investment strategies, which is associated with greater risk tolerance (Kumar et al., 2023; Okręglicka et al., 2021). Akben-Selcuk (2015), in a study involving college students, found that men are less inclined toward systematic budget planning, whereas Long and Tue (2024) reported that women demonstrate more responsible financial behaviour than men, particularly in terms of budgeting, saving, and long-term financial planning. Some studies indicate that generally both genders have similar approaches to savings and expenses monitoring, while financial investments were primarily pursued by men, and these differences can being explained partly by different conceptions and attitudes towards money, with men often looking at it as a symbol of success and power and women - as both a source of anxiety and a means to ensure security and prove their love (Sesini et al., 2023). Findings on gender differences in mindfulness are different and scarce. For example, Alomari (2023) found that university students had a moderate level of mindfulness with no significant gender differences, whereas Vidic (2024) demonstrated that females experienced a greater decrease in maladaptive coping compared to the males following a relaxation and mindfulness-based intervention in an academic course.

Findings indicate that mindfulness may influence financial behaviour indirectly through financial self-efficacy, and that gender might be the factor that shapes this process. Mindfulness interventions may enhance

psychological resources differently across genders (Vidic, 2024). Possibly, mindfulness can facilitate women's confidence in their capability to manage finances and support men in moderating risk-taking tendencies (Iram et al., 2023). In the financial domain, mindfulness represents a promising area of research, while the role of financial self-efficacy, particularly in relation to gender differences, offers further opportunities for investigation. Exploring these mechanisms can deepen understanding of how psychological traits interact with financial behaviour and provide a basis for financial education approaches.

Research Methods

Sample of the study. Students at the College of Business Administration (CBA) participated in the study. CBA is a private college that provides a short-cycle higher professional education in seven study programmes in two study directions - Management, Administration, and Real Estate Management (six study programmes) and Law (one study programme). During the data collection period, the target population comprised 1400 students, of whom 715 agreed to participate in the survey (response rate = 51.1%). Seven respondents (1%) did not disclose their gender, therefore, their responses were excluded from further analysis. Respectively, responses of 708 students were included in the statistical analysis to explore gender differences. The sample consisted predominantly of female students (n = 594; 83.1%), with males representing (n = 114; 15.9%). The mean age of participants was 33.7 years (SD = 9.8), ranging from 19 to 61; the average age was 33.8 years (SD = 9.8) for female students and 33.9 years (SD = 9.4) for male students. Table 1 presents the sociodemographic characteristics of the sample in the total group and separately by gender. It summarizes participants' age distribution, year of study, educational background, occupational status, household income, credit obligations, and family status.

Table 1. Sociodemographic characteristics of participants (in total sample and by gender)

Category	Subcategory	Total sample N (%)	Females n (%)	Males n (%)
Age	18-24 years	23%	136 (22.9%)	28 (24.6%)
	25-30 years	17%	103 (17.3%)	17 (14.9%)
	31-36 years	21%	133 (22.4%)	18 (15.8%)
	37-43 years	22%	118 (19.9%)	34 (29.8%)
	44 years and more	17%	104 (17.5%)	17 (14.9%)
Year of the studies	1st year (1st and 2nd semester)	382 (53.4%)	312 (52.5%)	66 (57.9%)
	2nd year (3rd and 4th semester)	308 (43.1%)	263 (44.2%)	43 (37.7%)
	3rd year (5th semester)	24 (3.4%)	19 (3.2%)	5 (4.4%)
Education level	Secondary education	549 (77.5%)	457 (76,9%)	92 (80.7%)
	Higher education (short-cycle, bachelor or master degree)	159 (22.5%)	137 (23.1%)	22 (19.3%)
Occupational status	Employed	490 (69.2%)	415 (69.9%)	75 (65.8%)
	Entrepreneur or self-employed	63 (8.9%)	49 (8.3%)	14 (12.3%)
	Employed AND entrepreneur/ self-employed	64 (9.1%)	47 (7.9%)	17 (14.9%)
	Housewife/on parental leave	37 (5.2%)	37 (6.2%)	-
	Unemployed	54 (7.6%)	46 (7.7%)	8 (7.0%)
Household income per month (euros)	up to 1000 euros	82 (11.6%)	72 (12.1%)	10 (2.6%)
	1001 - 2000 euros	252 (35.6%)	214 (36.0%)	38 (33.3%)
	2001 - 3000 euros	160 (22.6%)	136 (22.9%)	24 (21.1%)
	More than 3001 euros	109 (15.4%)	86 (14.5%)	23 (20.2%)
	No response	105 (14.9%)	86 (14.5%)	19 (16.7%)
Credit obligations	Yes	408 (57.6%)	339 (57.1%)	69 (60.5%)
	No	271 (38.3%)	229 (38.6%)	42 (36.8%)
	No response	29 (4.1%)	26 (4.4%)	3 (2.6%)

Participants represented a broad age range, with a substantial proportion of adult learners: approximately 43% were between 31 and 43 years old, and 17% were aged 44 years or older. Thus, the sample predominantly

comprised mature students likely balancing studies with work and family responsibilities, which is particularly relevant in the context of financial behaviour. More than half of the participants (53.4%) were in their first year of study, while 43.1% were in their second year. The majority of students had secondary education (77.5%), and nearly one quarter already held a higher education degree. Most respondents were economically active: 69.2% were employed, and an additional 18% reported being self-employed or combining employment with entrepreneurial activity. Household income was most commonly reported in the range of 1001–2000 euro (35.6%), followed by 2001–3000 euro (22.6%). More than half of the sample (57.6%) reported having credit obligations. Regarding family status, 44.1% were married and 28.6% were in a partnership, while 17.9% were single. Gender distributions across most sociodemographic categories depicted in Table 1 were broadly comparable, although male students were somewhat more likely to be single and to report higher household income levels.

Data collection methods. A comprehensive questionnaire was designed to assess various dimensions of financial literacy and related psychological constructs, meanwhile the present study draws on a subset of the questionnaire, specifically the following measures:

1) mindfulness - measured with Cognitive and Affective Mindfulness Scale - Revised (CAMS-R; Feldman et al., 2006). The CAMS-R is a brief self-report instrument designed to capture mindfulness as a multidimensional construct, encompassing attention to the present moment, awareness, acceptance, and non-judgment of internal experiences. The scale consists of 12 items reflecting individuals' tendency to remain attentive and receptive to present-moment experiences in daily life. The Latvian version adapted by Skrule in 2021 was used in this study. Participants rated how often they experienced each statement (e.g., "I am able to focus on the present moment") on a 4-point scale (1 - very rarely or never, 4 - almost always). Scores on the CAMS-R were averaged to produce a total mindfulness score, with higher scores indicating greater mindfulness (Feldman et al., 2006).

2) financial behaviour - OECD INFE (Organisation for Economic Co-operation and Development/International Network on Financial Education) Financial Behaviour measure (OECD, 2023). It captures various aspects of responsible financial actions, such as budgeting, saving, timely bill payment, and prudent spending decisions, and creates a composite score. Items had different response scales (e.g., yes/no, 5-point Likert scale, multiple-response format, or frequency-based scale). The original OECD INFE Financial Behaviour measure allows for a maximum of 9 points, but two of its items related to seeking financial advice were omitted in the present study (to reduce participant burden, as the overall questionnaire included a broad range of psychological and behavioural constructs), so the maximum possible score was 7. The translation of the items established by the Bank of Latvia was used. Each item was recoded according to the scoring guidelines in a dichotomous way as 1 or 0. Table 2 summarizes the original (11 items) and adapted Financial behaviour measure (9 items) and its scoring principles.

Table 2. Original domains of OECD/INFE Financial Behaviour measure and adaptation in the present study

Domain	Item codes	Included in study	Scoring
Budgeting	QF1, QF2	Yes	1 point if respondent reports sole or joint responsibility for day-to-day household financial decision-making (QF1) **and** engagement in at least two active money-management behaviours (QF2).
Active saving	QF3	Yes	1 point if respondent reports saving through at least one active saving method in the past 12 months (excluding pension schemes).
Not borrowing to make ends meet	QF11, QF12	Yes	1 point if respondent did not experience an income shortfall in the past 12 months (QF11 = No) **or** experienced a shortfall but did not use borrowing or credit-related strategies (QF12).
Choosing financial products	QP5, QP7	**No**	The excluded domain (QP5, QP7) assessed informed product choice behaviour, including comparison of options and use of information sources (e.g., independent advice, personal networks, advertising).
Keeping watch on financial affairs	QS1_5	Yes	1 point if respondent agrees or completely agrees with closely monitoring their personal financial affairs (responses 1–2 on 5-point agreement scale).
Striving to achieve goals	QS1_8	Yes	1 point if respondent agrees or completely agrees with setting and striving toward long-term financial goals (responses 1 - 2 on 5-point agreement scale).
Careful consideration before purchase	QS2_3	Yes	1 point if respondent reports always or often considering affordability before making a purchase (responses 1–2 on 5-point frequency scale).
Paying bills on time	QS2_5	Yes	1 point if respondent reports always or often paying bills on time (responses 1–2 on 5-point frequency scale).

Note. Item codes correspond to the OECD/INFE Notes on methodology (OECD, 2023)

Financial behaviour score was used as a composite index which can be used for examining correlations with psychological predictors despite not functioning as a psychometric scale. As this index is composite, internal consistency is often lower than psychometrically acceptable. Van Hove and Ahunov (2024) have reported

that internal consistency of financial literacy tests are similarly low across countries (Cronbach alphas in 10 European countries were between 0.34 and 0.54), and mainly can present problems when country rankings are executed.

3) financial self-efficacy was measurd with the five-item Financial Self-Efficacy scale by Loke & Choi (2015). Authors translated the scale from English to Latvian using a parallel translation procedure, in which two independent translations of five scale items were produced and subsequently compared and harmonized to ensure conceptual equivalence. Study participants rated their confidence to effectively and in a responsible manner do five financial actions (*"How sure are you that you can effectively do each of the following in a responsible manner during your lifetime?"* - the items included: "Use credit," "Invest your money," "Budget your money," "Spend your money," and "Save your money."). Responses were rated on a 4-point scale (1 - not sure at all to 4 - very sure). Item scores were averaged to compute an overall financial self-efficacy score, with higher scores indicating greater perceived financial capability.

Procedure. The survey was conducted in May and June 2024. The link to the questionnaire on Google Forms was distributed to all 1st to 4th semester students of CBA within the study course "The professional skills development practice" where students had an assignment to reflect on the questionnaire as a data collection method. After reviewing all questions in the questionnaire, students could submit their responses or leave it without completing. The survey link was sent to 5th semester students by the Study Support Centre of CBA. Access to the responses was restricted to two research team members, and anonymity of the responses was maintained.

Data analysis. Statistical analysis was conducted using IBM SPSS Statistics 31.0. Descriptive statistics were used to summarize measured variables, and Spearman correlation analysis was employed to examine the relationships between mindfulness, financial self-efficacy, and financial behaviour. To examine whether the scales functioned similarly across gender, internal consistency and factor structure were evaluated separately for males and females. We used PROCESS macro (v5.0) Model 4 to assess financial self-efficacy's mediating effect in the link between mindfulness and financial behaviour. Subsequently, Model 58 was employed to explore whether the indirect effect was conditional on gender by allowing moderation of both the X → M and M → Y paths. Moderated mediation tests for group differences directly in a single model, minimizing bias and power loss that may occur when data are split; it uses the entire sample and tests interaction terms, making it a formal inferential test of whether indirect effects depend on a moderator, in contrast to running mediation separately in each group, which are problematic because they do not formally test whether indirect effects differ across groups and can lead to misleading conclusions (Hayes, 2018). Moderator variable - gender - was coded as binary (0 = men, 1 = women). The significance of indirect effects was evaluated using 5,000 bias-corrected bootstrap samples and 95% confidence intervals. Moderated mediation was supported when the 95% confidence interval for the Index of Moderated Mediation excluded zero. No covariates were included in analysis.

Results

The primary purpose of this study was to examine whether the relationship between mindfulness and financial behaviour is mediated by financial self-efficacy and whether this pathway is moderated by gender. Prior to testing the mediation model, preliminary analyses were conducted to examine the measurement properties of the study variables separately for male and female students. Internal consistency was assessed using Cronbach's alpha, item-level analysis was done for measures, and exploratory factor analyses were performed to evaluate whether the scales exhibited comparable factor structures across gender groups.

Reliability and Structure of Measures. Internal consistency of the adapted Financial Behaviour measure in the total sample was relatively low (Cronbach's α = .43), with comparable coefficients observed in the female and male subsamples (.42 vs .49). As noted in the section of Data collection methods, the Financial behaviour score represents a composite index of heterogeneous financial actions rather than a unidimensional psychometric scale; therefore, lower internal consistency coefficients are expected and consistent with prior research. The measure was treated as a formative composite suitable for examining associations with psychological predictors.

CAMS-R demonstrated good internal consistency in the total sample (Cronbach's α = .80) and in both gender groups (α = .79 for females; α = .83 for males). Item-level analyses indicated satisfactory item means (2.01 - 3.03) and acceptable corrected item-total correlations (r = .26 - .65). One item („I am preoccupied by the past") showed a negative corrected item–total correlation (- .10), suggesting poor fit with the remaining items and was excluded, resulting in an 11-item scale with improved reliability (α = .83 in total sample). Cronbach's alpha for females and males (.83 and .85) indicated consistent internal functioning of the scale.

The Financial Self-Efficacy scale, translated and adapted for the present study, demonstrated acceptable internal consistency in the total sample (Cronbach's α = .76), comparable to that reported in the original validation study by Loke and Choi (2015). Cronbach's alpha was .76 for females and .72 for males, indicating similar reliability across gender groups. Item-level analyses showed satisfactory item functioning, and corrected item-total correlations were within acceptable ranges (r = .26 - .65), supporting the internal coherence of the adapted measure.

Because gender was examined as a potential moderator of the mediation process, exploratory factor analyses were conducted in the total sample and separately by gender to ensure that the measures demonstrated comparable structural patterns across groups (see Table 3).

Table 3. Summary of exploratory factor analyses in the total sample and by gender

Measure	KMO			Variance explained by Factor 1		
	Total sample	Females	Males	Total sample	Females	Males
Financial behaviour	.61	.61	.62	13.1%	12.9%	16.2%
Mindfulness	.85	.84	.84	34.3%	33.8%	37.8%
Financial self-efficacy	.77	.78	.74	44.3%	45.4%	39.9%

Note. Females n = 594, males n = 114; KMO = Kaiser–Meyer–Olkin measure of sampling adequacy. Values > .60 indicate acceptable factorability.

Sampling adequacy was acceptable for the CAMS-R and Financial Self-Efficacy scale (KMO ≥ .74) and borderline for the Financial Behaviour measure (KMO ≈ .61). A dominant first factor was observed for CAMS-R and Financial Self-Efficacy scale across the total sample and both gender groups, explaining approximately 34-38% and 40-45% of the variance, respectively. The Financial behaviour items did not form a clear unidimensional factor, with low variance explained (approximately 13-16%) and heterogeneous loadings, supporting their treatment as a composite index of distinct financial actions rather than a reflective latent scale. Similar structural patterns were observed across female and male subsamples, suggesting no substantial dimensional differences between gender groups. These findings provided preliminary support for the structural adequacy and comparability of the reflective measures used in subsequent regression analyses.

Tests of normality (Shapiro-Wilk test) indicated that only mindfulness scores among male students were normally distributed, whereas all other variables deviated significantly from normality.

Descriptive statistics of financial behaviour, mindfulness, and financial self-efficacy. Results in Table 4 indicate that financial behaviour scores on average were relatively high, whereas mindfulness and financial self-efficacy scores were slightly above medium level. Descriptive statistics indicate comparable means and variability across gender groups, providing the groundwork for testing the hypothesised mediation model.

Table 4. Descriptive statistics and gender differences in financial behaviour, mindfulness and financial self-efficacy

Variable (scale)	**Sample**	***M (SD)***	***Mdn***	**Range**
Financial behaviour (0-7)	Total sample	5.5 (1.26)	6.0	0-7
	Females	5.5 (1.26)	6.0	0 - 7
	Males	5.6 (1.28)	6.0	2 - 7
Mindfulness (1-4)	Total sample	2.9 (0.50)	2.8	1.5 - 4.0
	Females	2.8 (0.49)	2.8	1.6 - 4.0
	Males	2.9 (0.52)	2.8	1.5 - 4.0
Financial self-efficacy (1-4)	Total sample	2.9 (0.59)	3.0	1.0 - 4.0
	Females	2.9 (0.59)	3.0	1.0 - 4.0
	Males	2.9 (0.54)	3.0	1.6 - 4.0

Note. Females n = 594, males n = 114

Bivariate associations of study variables. To provide a basis for the subsequent mediation analysis, we explored the correlations among mindfulness, financial self-efficacy, and financial behaviour overall and for male and female students separately using Spearman's r (see Table 5).

Table 5. Spearman correlations among mindfulness, financial self-efficacy and financial behaviour

Variable pair	Total sample r_s	Females r_s	Males r_s
Mindfulness - Financial behaviour	.23**	.24**	.17
Mindfulness - Financial self-efficacy	.33**	.31**	.39**
Financial self-efficacy - Financial behaviour	.37**	.37**	.34**

Note. Females n = 594, males n = 114; *p < .05. **p<.01

As presented in Table 5, mindfulness was positively associated with both financial behaviour and financial self-efficacy. Correlation magnitudes were broadly similar across females and males. The association between mindfulness and financial behaviour was modest overall (r = .23), and reached statistical significance for females (r = .24, p < .01), but not for males (r = .17, p = .08). The link between mindfulness and financial self-efficacy was .33, and it was relatively stronger in males (r = .39, p < .01) compared to females (r = .31, p < .01). Financial self-efficacy was positively related to financial behaviour in both groups, with almost identical correlations (female r = .37, male r = .34; p < .01). Thus, mindfulness was positively associated with financial behaviour and financial self-efficacy overall and within both gender groups. These descriptive patterns do not formally test whether the mediation mechanism differs by gender and whether indirect effects vary across groups. A moderated mediation analysis was conducted to examine whether the indirect effect of mindfulness on financial behaviour through financial self-efficacy varied by gender.

Mediation of mindfulness and financial behaviour through self-efficacy. Prior to conducting mediation analyses, assumptions of linear regression were examined. Collinearity diagnostics indicated no multicollinearity concerns (VIF = 1.12; tolerance = .89).

Given the use of bootstrapped confidence intervals, normality of indirect effects was not assumed.

First, a simple mediation model (PROCESS Model 4) was estimated to examine whether financial self-efficacy mediated the association between mindfulness and financial behaviour (see Table 6).

Table 6. Mediation analysis of the effect of mindfulness on financial behaviour through financial self-efficacy

Path / Effect	*B*	*SE*	*t*	*p*	95% CI
a path: Mindfulness → Financial self-efficacy	0.38	0.04	9.14	< .001	[0.30. 0.46]
b path: Financial self-efficacy → Financial behaviour	0.70	0.08	8.76	< .001	[0.54, 0.86[
c′ path: Mindfulness → Financial behaviour (direct)	0.31	0.09	3.37	< .001	[0.13, 0.50]
Indirect effect (a × b) via Financial self-efficacy	0.27	0.05	-	-	[0.18. 0.38]

Note. $N = 708$; *B* = unstandardized coefficient; *SE* = standard error; CI = confidence interval. Indirect effects were estimated using 5,000 bias-corrected bootstrap samples. Effects are considered statistically significant when the 95% CI does not include zero.

A mediation analysis indicated that mindfulness significantly predicted financial self-efficacy ($B = 0.38$, $SE = 0.04$, $p < .001$), explaining 11% of its variance. In the outcome model, both mindfulness ($B = 0.31$, $SE = 0.09$, $p < .001$) and financial self-efficacy ($B = 0.70$, $SE = 0.08$, $p < .001$) significantly predicted financial behaviour, with the model explaining 15% of the variance. The indirect effect of mindfulness on financial behaviour through financial self-efficacy was significant ($B = 0.27$, 95% CI [0.18, 0.38]), indicating partial mediation. It suggests that financial self-efficacy statistically mediates the association between mindfulness and financial behaviour; approximately half of the total effect of mindfulness on financial behaviour operated through financial self-efficacy, while a significant direct effect remained.

To explore whether the mediation varied by gender, a moderated mediation model (PROCESS Model 58) was estimated, allowing gender to moderate both the mindfulness → financial self-efficacy (a path) and financial self-efficacy → financial behaviour (b path) associations, to formally test whether the indirect effect differs between male and female students (see Table 7).

Table 7. Moderated mediation of the effect of mindfulness on financial behaviour via financial self-efficacy, moderated by gender

Effect	*B*	*SE*	*p*	95% CI
Interaction effects				
Mindfulness x Gender → Financial self-efficacy	- 0.03	0.11	.79	[-0.25, 0.19]
Financial self-efficacy x Gender → Financial behaviour	0.02	0.22	.93	[-0.41, 0.45]
Conditional indirect effects (Bootstrapped)				
Males (0)	0.28	0.11	-	[0.09, 0.52]
Females (1)	0.26	0.06	-	[0.17, 0.39]
Index of moderated mediation	- 0.01	0.12	-	[-0.27, 0.21]

Note. *B* = unstandardized coefficient; *SE* = standard error; CI = confidence interval. Bias-corrected bootstrap CIs (5,000 resamples) are reported for indirect effects. Effects are considered statistically significant when the 95% confidence interval does not include zero; Females $n = 594$, males $n = 114$

The interaction between mindfulness and gender predicting financial self-efficacy was not significant ($B = -0.03$, $SE = 0.11$, $p = .79$). Similarly, the interaction between financial self-efficacy and gender predicting financial behaviour was not significant ($B = 0.02$, $SE = 0.22$, $p = .93$). Thus, the association between mindfulness and financial self-efficacy did not differ by gender, as well as there were no gender differences in the self-efficacy and financial behaviour link. Conditional indirect effects were significant for both male ($B = 0.28$, 95% BC CI [0.09, 0.52]) and female students ($B = 0.26$, 95% BC CI [0.17, 0.39]). However, the index of moderated mediation was not significant (Index = -0.01, 95% BC CI [-0.27, 0.21]), indicating that the indirect effect of mindfulness on financial behaviour through financial self-efficacy did not differ by gender.

Conclusions

Understanding the factors predicting financial behaviour, including psychological characteristics, is useful to develop approaches tailored to financial education. Formal financial education alone does not automatically result in better financial behaviour - although many studies have focused on improving individuals' financial knowledge and literacy through educational initiatives, managing personal finances requires more than these skills (Olajide et al., 2025).

This study examined the role of mindfulness and financial self-efficacy in students' financial behaviour and the mechanism linking these constructs, while also exploring potential gender differences. Mindfulness, a trait linked to self-regulation and focused awareness, and financial behaviour in college students was partially mediated by financial self-efficacy. Fostering students' awareness and self-regulatory capacities may be linked to stronger financial confidence, which is associated with more responsible financial behaviour. The moderated mediation analysis showed that this psychological mechanism operated similarly across male and female students. Potentially, financial education initiatives might be strengthened by incorporating components that support both financial skills and psychological resources.

In addition to testing the mediation model and examining whether the indirect effect differed by gender, the study examined gender differences in financial behaviour, mindfulness, and financial self-efficacy, given the mixed findings in prior research. The study found no significant differences between genders in measures of mindfulness, financial behaviour and financial self-efficacy, contrasting a number of previous studies (Furrebøe & Nyhus, 2022; Long & Tue, 2024) but aligning with a recent Latvian studies which also reported near-equal outcomes between men and women in financial behaviour (Latvijas Banka, 2022). Within a higher-education setting, where students balance academic and financial responsibilities and self-fund their studies, gender may be less decisive than factors such as access to education, financial socialization, and evolving social norms. Gender disparities in financial behaviour may be context- and life-stage dependent (Long & Tue, 2024). It is also possible that individuals who pursue higher education already possess relatively stronger financial self-efficacy, contributing to convergence across genders.

By examining students in higher professional education, the findings extend theoretical discussions of financial socialization beyond adolescents or young undergraduates since adult students at different life stages balance studies with work, family, and financial responsibilities. Interventions during this period may have a long-lasting impact on financial stability and well-being. Since college students may face distinctive pressures, e.g., limited income, debt from tuition, taking care of their families, they may be particularly responsive to interventions that strengthen self-regulation and confidence in managing money.

The study has several limitations. First, the sample was drawn from a single distance-learning college in Latvia, where all participants had at least secondary education and were self-financing their studies, which limits the generalizability of the findings to other higher-education contexts and broader populations. Second, the substantially smaller number of male participants may have reduced statistical power to detect interaction effects in the moderated mediation analysis. Third, the financial behaviour measure was based on the OECD INFE framework but used an adapted (shortened) version, which may affect strict comparability with studies using the original format. Fourth, the observed relationships between mindfulness, financial self-efficacy, and financial behaviour may be influenced by relevant covariates (e.g., age, socioeconomic status, family background, personality traits, or financial knowledge) that were not controlled for in this study. Finally, the use of self-report measures may introduce bias, as participants may overestimate socially desirable behaviours or underreport negative practices. Future research could address these limitations by using more diverse samples, incorporating additional control variables, examining subdimensions of financial behaviour, and combining self-reported and objective financial behaviour data.

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NEED FOR NURSE SPECIALIST WORKFORCE IN LITHUANIA AND EUROPEAN UNION: CURRENT SITUATION AND FUTURE OUTLOOK

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Abstract
The healthcare workforce is one of the most important resources of the healthcare system, directly influencing the accessibility, quality, and long-term sustainability of healthcare services. In recent years, a significant shortage of nurses has been observed in Lithuania as well as in many European Union countries, making this issue increasingly relevant in the context of health policy and organizational management. Demographic changes, population ageing, the growing prevalence of chronic diseases, and rising patient expectations increase the demand for nursing services; however, the pace of nurse education and retention often fails to meet these growing needs. This article analyzes the shortage of nurses in Lithuania and the European Union, aiming to assess the imbalance between the supply and demand of the nursing workforce and its impact on the healthcare system. The analysis is based on a review of national statistical data, European Union indicators, international reports, and administrative assessments from healthcare organizations. The article compares indicators related to the number of nurses, age structure, workload, and migration trends, which allows for the identification of both common and region-specific challenges across different healthcare systems. The findings indicate that the shortage of nurses has a negative impact on the continuity of healthcare service provision, increases staff workload, raises the risk of professional burnout, and may lead to challenges related to service quality and patient safety. In Lithuania, this problem is particularly pronounced in regional areas, where opportunities to attract healthcare personnel are limited and the ageing of the workforce is more evident. At the European Union level, similar trends are observed, although their intensity varies depending on national healthcare system organization and workforce policy measures. The article emphasizes that addressing the shortage of nurses requires a comprehensive approach that integrates strategic workforce planning at the national level with effective organizational management solutions. To ensure the long-term sustainability of the nursing workforce, investments are needed in nurse education, enhancement of professional attractiveness, development of career opportunities, improvement of working conditions, and implementation of staff retention measures. Coordinated, data-driven strategies can contribute to the development of a more stable and efficient healthcare system in Lithuania and the European Union.
KEY WORDS: workforce resources; Lithuania; European Union; staffing shortage management; health care, strategic planning, nurse specialists.
JEL classification: I11; I18

Introduction

The scientific **purpose** of this study is to contribute to the analysis of healthcare workforce planning and management by examining the extent of the nursing shortage and its relationship with the functioning of the healthcare system in Lithuania and the European Union. The study aims to expand scientific knowledge on the imbalance between the supply and demand of nursing personnel and to provide evidence-based insights that may be applied in the development of healthcare policy and organizational management decisions.

The novelty of the study lies in its comprehensive assessment of the nursing shortage through the integration of national data from Lithuania with the broader European Union context.. In Lithuania, this issue is further complicated by the low specialist to population ratio, workforce aging and international migration. Effective workforce management and human resource management solutions are turning into a strategic priority for health care institutions.

The goal of this study is to conduct analysis the need for general practice nurses, to identify the reasons for employee shortage and to suggest certain management solutions applicable in Lithuania with respect to the trends prevalent in the European Union. In the European Union, the average nurse to population ratio is 8.4 to 1000. Yet, this ratio tends to differ a lot among state members and is deemed insufficient with respect to the growing health care needs. The situation in Lithuania is exceptional because its nurse to population ratio is lower than the European Union average and stands at about 7.5-7.9 to 1000. According to the national assessment results, there is a shortage of approx. 3000 nurses in Lithuania at this very moment. If the current tendencies remain the same, this number may grow to 4500-5000 within the upcoming several years. Furthermore, long-term outlook presupposes that the general shortage of general practice nurses, assistant nurses and other health care specialists may exceed 4600 individuals in 2032. In consideration of these circumstances, it is evident that the nurse workforce issue requires consecutive and data-based research. Thus, this study is focused on analyzing the need for specialist nurses in Lithuania and European Union with respect to national statistical data, international comparisons and political analysis insights, aimed at contributing to a more affective workforce management and improvement of health care sustainability. Unlike studies that focus on narrowly defined aspects of the issue, this research examines the nursing shortage not only as a quantitative phenomenon but also as a multifaceted issue related to demographic trends, working conditions, migration processes, and organizational management. This integrated approach enables the identification of both common and context-

specific factors influencing the nursing workforce shortage at different levels.

The study is classified as an **applied descriptive–analytical research**. It aims not only to describe the current situation of the nursing shortage but also to analyze key trends and their potential impact on the healthcare system. The research is oriented toward the practical applicability of its findings and provides a basis for further empirical or intervention-based studies. **The object of the study** is the relationship between the supply and demand of the nursing workforce within the healthcare system in Lithuania and the European Union.

The following methods are applied in the study:

- analysis of scientific literature and strategic policy documents;
- secondary data analysis using national statistical indicators and European Union databases;
- comparative analysis to evaluate nursing shortage trends in Lithuania and other European Union countries;
- logical and systemic analysis for the interpretation and synthesis of the research findings.

Literature Review

In scientific literature, the shortage of nurse specialists is named as one of the most significant challenges faced by modern health care systems in Europe and Lithuania. According to the reports of the Organization for Economic Co-operation and Development (OECD), health care institutions are understaffed due to the growing need for health care services and such structural factors as society aging, workforce aging and limited appeal of health care profession (OECD, 2024). The analysis carried out by European Parliamentary Research Service (EPRS) also notes the unfair distribution of health care specialists among regions and the underdeveloped long-term workforce management systems that impede steady health accessibility (EPRS, 2025).

According to the World Health Organization (WHO), the global shortage of nurse specialists is further affected by international migration, insufficient investments into vocational training and difficult working conditions that lower employee retention (WHO, 2025). In terms of Lithuania, studies and auditor's reports have shown that the nurse to population ratio remains lower than the European Union average and the workforce data collection and long-term management issues further limit effective decision making (Official Statistics Portal (OSP), 2022; National Audit Office of Lithuania, 2023). Outlook assessment allows presuming that the shortage of nurse specialists might only grow within the upcoming ten years due to emigration and the increasing number of older employees in the workforce (OECD, 2025). Many foreign and Lithuanian authors who have examined the training of nursing professionals pay considerable attention to addressing the issues of health tourism. As the economy develops, the demand for health tourism services increases, which in turn creates a need for nursing professionals in this field (Daniel, et al., 2017; Martikonytė, et al., 2020; Langeland, et al., 2022; Lileikienė, et al., 2024; Semutis, et al., 2024).

The results of the empirical research further reveal that a significant portion of nurse specialists are considering requalification or looking for work abroad, which, in turn, signify the importance of systemic employee retention measures and improvement of work conditions (Šablinskas & Stankūnas, 2025). To summarize literature review, one could say that the problem of shortage of nurse specialists requires coordinated solutions focused on long-term workforce stability on both national and European level.

The needs of the labor market and the trends in the choice of studies show that medicine is becoming more popular study programs in the field of science. As attention to individual and public health increases, qualification requirements for healthcare professionals, and especially nurses.

The right profession is of great importance for job offers for every person, simply because it spends a third of his life in it. Therefore, it is necessary to strive for the chosen profession to best meet the needs, inclinations and

possibilities. One of the possibilities to ensure the future in terms of work is the right choice of profession, appropriate vocational training and integration into the labor market.

The experience of foreign countries shows that nursing is important for health care component of the system at the global and national level. The observations made show that the need for nursing care will continue to increase, regardless of the ongoing health care reforms. The latter processes are also characteristic of Lithuania. After ceasing to prepare medical paramedics, emergency medical aid specialists can become general practice nurses. Unfortunately, the state order for these specialists has not yet been at the required levels, as well as the need for motivation of general practice nurses.

Research Methods

Secondary data from 2018-2025 year included the Organization for Economic Co-operation and Development, World Health Organization, Official Lithuanian statistics portals and public reports of the National Audit Office of Lithuania were used in the research. Data analysis encompassed descriptive statistics, comparison of national ratios and average European Union ratios, and long-term workforce outlook assessment. The results were presented in tables and diagrams, revealing the nurse to population ratio, migration trends and dynamics of workforce changes. The descriptive cross-sectional study was carried out to better assess the interaction between the supply and demand of general practice nurses in Lithuania and the possible developmental trends of this professional group within the next ten years. The goal of the study was to assess the situation of training general practice nurses in Lithuania, to determine the supply and demand ratio in Vilnius and Klaipėda Regions and to assess the appeal of the nursing study program in the labor market.

The sample was made up of inpatient and outpatient health care institutions (hospitals, multi-specialty clinics, family health centers) located in Vilnius City, Klaipėda City and the corresponding regions. The research data were collected using the Likert scale structured survey

prepared by the authors and distributed to the representatives of the administrative units of health care institutions (senior nurses, nurse administrators, human resource or documentation specialists) who were able to impartially assess the need for nurses at their institution. The surveys were sent to a total of 110 health care institutions. The response rate was 42.7%. A total of 47 respondents took part in the study. The survey was comprised of three sections: assessment of the need for general practice nurses, analysis of the significance of the nurse administrator and general information about the institution. The respondents were duly informed about the goal of the study, voluntary participation, confidentiality and personal data processing for research purposes. The data was collected electronically until November 14, 2025. Participation was voluntary. The survey was submitted along with information on the goal of the study, confidentiality and personal data processing for research purposes. As many as 63.6% of the respondents replied that the shortage of general practice nurses negatively affected patient care quality and safety. Meanwhile, 45.5% of the respondents confirmed that their institutions were understaffed and in need of qualified nurses. They believed that the shortage of nurses would only increase within the next five years. Thus, the available general practice nursing study programs should be steadily improved, as claimed by 42.86% of the respondents. According to the research results, as many as 66.67% of the respondents claimed that they would support the initiative to cooperate with educational institutions and would provide students with nursing internship positions (Fig. 1.).

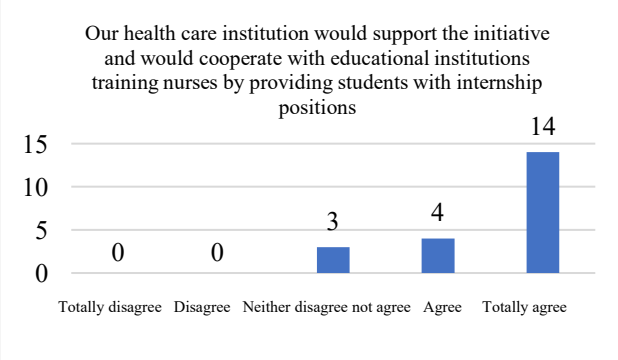

Fig 1. Initiative by health care institutions in providing internship positions to nurses
Source: research results

As of January 1 of the current year, health care institutions have introduced a new position of Nurse Administrator. As many as 61.9% of the respondents expressed their wish to gain managerial/ administrative work experience.

Results

Specialist nurses comprise one of the most important professional groups in the health care system. Patient care quality and continuity of health care services depend directly on their work. According to analyses carried out by international organizations, shortage of nurses is becoming a more relevant challenge in many countries, including Lithuania. The situation is observed on a national level and reveals structural disbalance in the number of doctors and nurses. Even though the physician to population ratio per 1000 residents in Lithuania exceeds the OECD average (4.5 per 1000 vs. 3.7 per 1000), the number of practicing nurses remains lower than the OECD average (7.9 per 1000 vs. 9.2 per 1000). The ratios of practicing ratios remain lower than the international standards. The research also reveals that the number of general practice nurses trained in Lithuania is also lower than the OECD average (27.4 per 1000 vs. 42.8 per 1000), which limits the possibilities to improve the current and future understaffing. The goal of attaining a balanced ratio of doctors and nurses have long been published in national strategic documents; however, the practical implementation of this matter remains limited due to insufficient number of well-trained specialists.

Based on the STRATA outlook reports, the shortage of general practice nurses, assistant nurses and advanced practice nurses might grow to significant proportions in Lithuania in 2032. The research also confirms that the understaffing might by influences by several interconnected factors, such as society and workforce aging, high workload, limited professional development possibilities, emigration and bad reputation of the nurse profession. All of these circumstances directly affect health care accessibility, patient waiting time and service quality. According to the research by Rastenienė, et. al (2023), there might be a shortage of 4643 general practice nurses, 2355 assistant nurses and 1328 advanced practice nurses in the near future. More than a third of health care institutions claim to be understaffed when it comes to nurses or assistant nurses. The questionnaire-based survey revealed that the majority of the respondents associated nurse shortage with negative effects on patient care safety and nursing efficiency. Many of the respondents also believed that the nurse shortage would increase in their institutions in the upcoming years. Due to this reason, the respondents highlighted the necessity to expand the offered nursing study programs and to improve cooperation with educational institutions by providing more internship positions to students. The official statistics show that the nurse to population ratio remains lower compared to the European Union average. Internal audits and policy evaluations reveal significant workforce data collection and long-term management deficiencies (OSP, 2022; National Audit Office of Lithuania, 2023) (Table 1).

Table 1. Number of nurses per 10000 residents in Lithuania and European Union (EU, 2022-2024)

Year	Number of specialist nurses in Lithuania	Population of 10000 in Lithuania	Number of specialist nurses in the EU	Population of 10000 in the EU
2022	22 177	78	3.8 million	400-900
2023	21 920	75	3.8 million	400-900
2024*	23 160	80	3.8 million	400-900

**Note: preliminary data of 2024. Source: OSP, Eurostat, OECD, European Commission*

OECD profiles suggest that Lithuania might face an increasing nurse shortage resulting from workforce aging and emigration in the next ten years, provided that no measures are taken to deal with this issue (OECD, 2025). Empirical research also confirms that many of the

Lithuanian health care specialists are intending to emigrate or change profession, which only highlights the importance of policy measures aimed at employee retention and improved work conditions (Šablinskas & Stankūnas, 2025). These conclusions also emphasize the need for coordinated national and European strategies to ensure sustainable nursing workforce. Nurse specialists play the main role in ensuring accessible and high-quality health care. However, the significant shortage of health care specialists in Europe threatens the provision of health care services and patient health results. The situation in Lithuania is further aggravated by the low nurse to population ratio, workforce aging and migration. Comprehensive understanding of the current workforce trends, policies and employee retention factors is essential to finding a solution for these challenges. According to research data, Lithuanian will experience a shortage of 10000 nurses in 2030-2035. The most recent OECD and EC report titled State of Health in the European Union: Lithuania – Country Health Profile 2025 claims that in 2032, Lithuania will most probably be in need of 8000 nurses.

It is not the big cities and large hospitals that suffer the most due to nurse shortage but rather the regions, where the disbalance is already prevalent due to the increased internal migration of doctors and nurses. This results in low health care accessibility. Approx. 40-50% of the presently employed nurses will end their career in the nursing sector in the next 10-15 years. According to Eurostat, the age group distribution shows that nurses aged 50 and more comprise almost half (~48.9%) of all the nurses in Lithuania. These reasons contribute to health care efficiency. The study of the need of nurses in Klaipėda and Vilnius Regions reveals the current trends (Fig. 2).

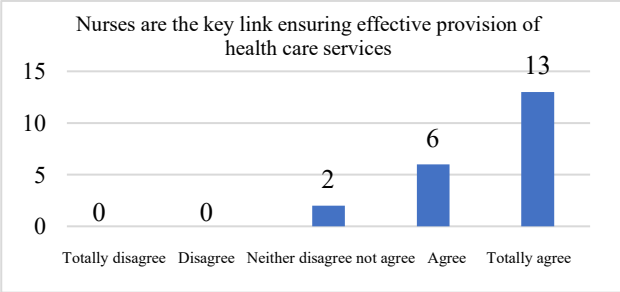

Fig. 2. Nurse efficiency in rendering services to patients
Source: research results

Nurse shortage in Lithuania is closely related to migration processes in the European Union. In 2022-2023, the nurse to population ratio in Lithuania was 7.5–7.8 to 1000. According to Eurostat, the European Union average nurse to population ratio was 8.5-9 as opposed to 12 to 1000 residents in several Northern European countries. This situation reveals that Lithuania is already facing structural nurse shortage which is further complicated by the emigration of specialists to economically stronger member states (e.g., Germany, Ireland or Scandinavian countries). The migration was prompted by salaries higher by 2-3 times, better working conditions and professional development possibilities. The workload of remaining specialists, especially those in regional health care institutions, only increase due to the migration of other nurses, which, in turn, contributes to employee burnouts and further migration risk. As about a third of Lithuanian nurses are older than 55 years and the society keeps aging rapidly, the migration of nurses is becoming one of the main factors that threaten health care system sustainability long-term (Fig. 3).

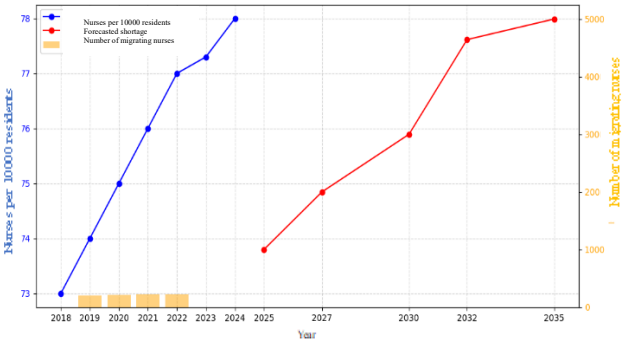

Fig. 3. Lithuanian nurse workforce data: ratio, migration and outlook
Source: Eurostat (2024). Healthcare personnel statistics. European Commission

The research results highlight that strategic HR management and management solutions are essential in all health care institutions. Even with increased training of nurse specialists, long-term workforce sustainability will not be ensured without career planning, motivation measures and workload adjustment. With respect to nurse specialist training, management solutions in health care could encompass investments into better working conditions, development of personnel career opportunities, employee retention strategies and international migration impact management measures. This is important for both Lithuania and other countries facing complex understaffing issues in the health care sector.

Discussion

The received research results allow presuming that the recent gradual increase in nurse to population ratio per 10000 residents in Lithuania might be related to higher study program accessibility and certain health policies. However, this growth is not sufficient to compensate for the forecasted workforce decrease associated with employee aging and changing professions. The forecasts for 2025-2035 reveal that nurse shortage might increase more rapidly than the earlier recorded nurse to population ratio growth, if no additional systematic interventions are made. Thus, an assumption is made that educational measures alone cannot ensure long-term system stability. Complex solutions encompassing salary increase, workload optimization, expansion of career possibilities and prevention of occupational burnouts are becoming the key factors in retaining the nurse specialists. The study reveals important trends in the Lithuanian health care sector. Compared to European Union average ratios, the nurse to population ratio and migration trends are different. Workforce aging, migration and current policy deficiencies remain significant challenges. To ensure sustainable workforce structure, it is recommended to take such measures as investments into the education sector,

efficient employee retention strategies and workforce management improvement.

Conclusions

The study reveals that the nurse shortage in Lithuania is a long-term structural problem, which is closely related to workforce aging, migration processes and insufficient strategic planning. Even though a gradual increase in the number of nurses was recorded from 2018 to 2024, this growth does not compensate for the forecasted workforce shortage in the future. Long-term nursing sector sustainability is dependent on coordinated solutions on the national and European level, which are focused not only on specialist training but also on work condition improvement, occupational burnout prevention and employee retention. The improvement of these measures might help to retain nurses at the institutions, mitigate the losses caused by migration and ensure sustainable health care services in Lithuania. The forecasted increase of nurse shortage in 2025–2035 reveals a structural disbalance between the demand for nurse services and the available human resources. The increasing number of nurses who quit work is becoming a key factor in the future massive nurse shortage, despite the earlier increase in nurse to population ratio. Long-term nursing sector sustainability in Lithuania requires complex health policy solutions focused not only on specialist training but also on improving work conditions, preventing occupational burnout and retaining nurses in employment.

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NEW CORRUPTION CHALLENGES IN THE CONTEXT OF DIGITAL TRANSFORMATION

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Abstract
The role of law enforcement institutions in the fight against corruption is important and indisputable. However, legal mechanisms for the fight against corruption are not enough. The issue of increasing the integrity and transparency of law enforcement institutions themselves is increasingly being raised. Today, new manifestations of corruption are becoming especially important when rapidly developing innovative digital technologies are used and new types of corruption appear. There are gaps in the existing system that hinder the fight against corruption. Therefore, it is necessary to raise the issue of strengthening the effectiveness of supervision and control of this criminal activity – from changes in legal regulation to strengthening institutional resources. The purpose of the study is to reveal the concept of corruption and judicial practice in combating the most advanced manifestations of corruption. The following research methods were applied: analysis of scientific literature and legal acts, data collection, systematization and generalization. The article presents criminal acts of a corrupt nature using data collection and systematization methods. In the Lithuanian Courts Information System, the public search system for court decisions and legal acts e.teismai.lt, available criminal case rulings for 2020–2025 were found, which allowed us to analyze the composition of corruption-related criminal acts in the practice of Lithuanian courts (Supreme Court of Lithuania, Klaipėda and Kaunas Regional Courts). Cases were selected that allowed us to reveal corruption-related criminal acts under Articles 225–228 of the Criminal Code of the Republic of Lithuania, to confirm or deny the signs of crimes, as well as to confirm or deny corruption-related acts related to the use of advanced technologies. Based on the results obtained, generalizing conclusions were formulated. Corruption is also characteristic of law enforcement institutions themselves, when law enforcement officers commit crimes for personal gain, disregard ethical norms, moral duties, the principles of honesty and transparency. 2020–2025 The analysis of case law has shown that corruption-related criminal acts are committed by civil servants holding different positions. Law enforcement officers themselves are also punished for bribery under Article 225 of the Criminal Code of the Republic of Lithuania, for trading in influence under Article 226 of the Criminal Code of the Republic of Lithuania, for bribery under Article 227 of the Criminal Code of the Republic of Lithuania and for abuse under Article 228 of the Criminal Code of the Republic of Lithuania. When making decisions in corruption cases, courts take into account whether the bribery was committed only with direct intent, whether the necessary elements of a criminal act are present, and whether the intermediaries being bribed are aware of the danger of the actions being taken and want to act in this way. The analysis of the fight against corruption by law enforcement institutions has led to the conclusion that corruption is multifaceted and undermines the rule of law and its security. The rule of law promotes equality of all citizens before the law, ensuring that no one, including leaders or other individuals, is above the law, and the law operates on the principles of accountability, transparency of government institutions and independence of the judiciary. However, after conducting an analysis of the case law in criminal acts of a corruption nature for 2020–2025, it was not possible to identify a single case where acts of a corruption nature were committed using advanced digital technologies.
KEY WORDS: corruption, digital transformation, advanced technologies, case law
JEL classification: K1, K10, K19

Introduction

The issue of corruption remains relevant and needs to be addressed. According to the Corruption Perceptions Index (CPI), Lithuania ranked 12th among EU countries in 2023 and 35th in the world (Transparency International CPI research data, 2024). Every year, the Special Investigation Service (STT) of the Republic of Lithuania initiates a study entitled "Lithuanian Corruption Map" showed that corruption ranks fifth among the most pressing problems in Lithuania (after inflation, low wages, healthcare problems, and drug use).

The United Nations Convention against Corruption (UNCAC) (Valstybės žinios, 2006-12-14, No. 136-5145, current version effective from 2007-01-20) defines corruption as a threat to the stability and security of society, democratic institutions, ethical values, and justice, posing a danger to the rule of law.

The novelty of the article lies in the fact that it analyzes the judicial practice of criminal offenses of a corrupt nature in Lithuania in the context of digital transformation, with particular attention paid to the possible use of advanced technologies in committing corrupt acts. In recent years, global scientific literature has been paying increasing attention to new forms of corruption related to the development of digital technologies, electronic payments, the use of cryptocurrencies, decentralized financial systems, and anonymous online platforms. Such technologies create the conditions for new mechanisms of corrupt activities, which are becoming more difficult to identify and prove for law enforcement agencies.

The innovative nature of this study is also linked to the fact that it analyzes whether these global digitalization trends are reflected in Lithuanian court practice. An analysis of criminal cases from 2020 to 2025 allows us to assess whether criminal acts of a corrupt nature in Lithuania are already linked to the use of advanced technologies or whether traditional forms of corruption still dominate. Such an analysis helps to identify possible gaps in legal regulation, law enforcement practice, or investigation methods related to the impact of technology on corruption.

The novelty of the article is also supported by significant events and trends in the fight against corruption in recent years. One of the most important events in Lithuania was the final decision of the Supreme Court of Lithuania in 2024 in the so-called MG Baltic political corruption case, which became one of the most significant precedents in assessing criminal acts of a corrupt nature and their proof in court practice. This case revealed complex mechanisms of corruption involving the interaction of politics, business, and interest groups, and showed that modern corruption often manifests itself not in direct bribery, but in complex financial schemes, intermediary relationships, and disguised transactions.

Corruption causes significant damage to society and undermines institutions by reducing trust in them and weakening their ability to implement public policy and provide high-quality public services. Preventing and combating corruption is essential to protecting EU values and the effectiveness of its policies, and to preserving the rule of law and trust in institutions and those in power (Joint Communication to the European Parliament, the Council, and the Lithuanian Economic and Social Committee on the fight against corruption, 2023).

The world and Lithuania have become accustomed to fighting everyday corruption and its manifestations, but new advanced technologies are creating new challenges in the fight against corruption in the context of digital transformation. As Zhang (2024) states, new manifestations of corruption are becoming relevant when advanced technologies are used (payments in the digital currency Bitcoin, red envelopes in WeChat groups, the Pay for Me system) and new, more difficult to detect types of corruption are emerging. The decentralization and anonymity of digital currencies facilitate illegal activities and provide a cover for bribery. There are gaps in the current system that hinder the fight against corruption. Therefore, it is necessary to raise the issue of strengthening the effectiveness of the supervision and control of this criminal activity, from changes in legal regulation to the strengthening of institutional resources.

Scientific sources examine forms of corruption, prevention, and discuss the role of law enforcement agencies in this prevention (Kratcoski, 2018; Ibodullaevich & Kholmomin, 2021; Singh, 2022; Hidayat et al., 2023; Suber, 2024; Mahendra et al., 2024). Saputra & Saputra (2021) discussed the factors of corruption, highlighting the needs, opportunities, and rationalization of this phenomenon. Zhang (2024) examined the manifestations and characteristics of new corruption, highlighting the influence of advanced technologies. Singh (2022) analyzed corruption among police officers and concluded that it is multifaceted and undermines the rule of law and security. According to this author, the rule of law promotes equality before the law by ensuring that no one, including rulers or other private individuals, is above the law, which functions with accountability, the transparency of open government, fair laws, and accessible and honest justice. Lytvyn et al. (2023, p. 154) stated in their study that "almost all states and all citizens face corruption, but in real life, most corrupt officials go unpunished, therefore, society has a false impression about the inevitability of punishment and about ways of solving problems that negate any measures and efforts to combat corruption". Zaksaitė (2024) analyzed in more detail the reflection of criminal policy for corruption-related crimes in the practice of law enforcement. The author discussed the MG Baltic case, the ambiguous assessment of the courts (in the first instance, all defendants were acquitted, and in the second, all were convicted) and stated that this case "could symbolize most of the problems in investigating corruption-related crimes: the complexity of the case, the intertwined connections between politics, business, and the media, and the changing concept of a 'bribe'" (Zaksaitė, 2024, p. 7).

The role of law enforcement agencies in the fight against corruption is important and indisputable. However, legal mechanisms alone are not sufficient to combat corruption. The question arises whether, in the last 2020–2025, there have been any corruption cases related to the most advanced digital technologies examined in court practice, and whether this has become a challenge for courts when examining cases related to the latest digital technologies. Therefore, it is appropriate to examine in more detail the composition of criminal offenses of a corrupt nature in Lithuanian court practice over the last 2020–2025 and to assess what measures could be implemented in the future to reduce corruption in Lithuania.

The aim of this paper is to reveal the concept of corruption and court practice in combating the most advanced manifestations of corruption.

The main objectives of the article are to analyze the concept and forms of corruption. To analyze court practice in criminal cases of a corrupt nature in the context of the most advanced technologies.

Methods: The concept and forms of corruption were examined by analyzing scientific literature and legal acts, and court practice was analyzed in order to identify the most advanced manifestations of corruption in the context of digital technologies. Data collection and systematization methods were used to analyze the composition of criminal acts of a corrupt nature in Lithuanian court practice in the context of advanced technologies. The summarization method was used to present summary insights and form conclusions.

Theoretical Background

The concept and forms of corruption are regulated in legal documents and examined in scientific works by Lithuanian and foreign authors, but there is no single universally accepted definition of corruption. In addition, attempts are being made to define the concept of corruption in the context of advanced technologies.

According to the Law on Corruption Prevention of the Republic of Lithuania (TAR, 2021-07-14, No. 15850, current version effective from 2022-01-01), a corruption-related violation of the law is "an administrative offense, a violation of work duties, or a misconduct committed by abusing authority and directly or indirectly seeking benefits for oneself or another person, as well as a criminal act of a corrupt nature". The 2022-2033 National Agenda for Corruption Prevention (TAR, 2022-07-07, No. 14816, current version effective from 2022-07-08) stipulates that not only civil servants but also natural and legal persons are liable for criminal acts of a corrupt nature. Several acts

falling under the category of criminal offences of a corrupt nature are specified (Fig. 1).

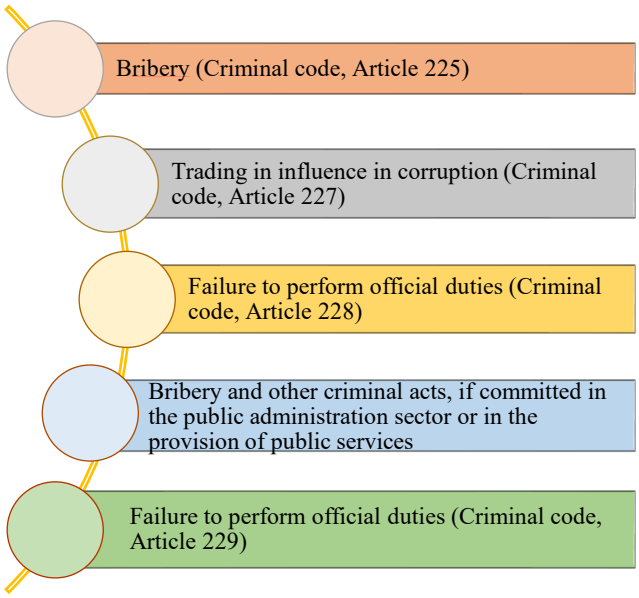

Fig. 1. Acts classified as criminal acts of a corrupt nature

Responsibility for acts of a corrupt nature is regulated by the Criminal Code of the Republic of Lithuania (Valstybės žinios, 2000-10-25, No. 89-2741, current version effective from 2000-10-25) Chapter XXXIII "Crimes and criminal offenses against public service and public interests". The following forms of corruption are distinguished:

- bribery (Article 225 of the Criminal Code of the Republic of Lithuania),
- trafficking in influence (Article 226 of the Criminal Code of the Republic of Lithuania),
- bribery (Article 227 of the Criminal Code of the Republic of Lithuania),
- abuse of office (Article 228 of the Criminal Code of the Republic of Lithuania),
- unlawful registration of rights to property (Article 2281 of the Criminal Code of the Republic of Lithuania),
- failure to perform official duties (Article 229 of the Criminal Code of the Republic of Lithuania).

The concept and forms of corruption are widely discussed in academic literature. According to D. Singh (2022), the word "corruption" comes from the Latin term "corruptus", meaning to disrupt, break, damage, or pollute. It is bribery, abuse of power for personal gain, even if the return is not achieved. Other benefits (maintaining support, loyal supporters, clients, political support, not just personal gain) may also be sought from the person in office.

Kratcoski (2018) describes corruption as a situation in which a person responsible for performing specific duties seeks an improper or unfair advantage by performing certain actions or failing to act as required by their position. Corruption can occur in all sectors of society, including public and private institutions, specific professional groups (e.g., lawyers, doctors), and private individuals. Forms of corruption include bribery, extortion, intimidation, gratitude payments, theft, etc.

Ibodullaevich & Kholmomin (2021) describe corruption as a cause of contradictions with the laws and moral norms that regulate public life. The authors distinguish the following types (kinds) of corruption: corruption in everyday life. This arises from interactions between ordinary citizens and officials. This includes various gifts and services provided by citizens to officials and their family members; corruption in business. This arises from the interaction between the government and business (e.g., in a business dispute, the parties may ask a judge for help in ruling in their favor); Corruption in the highest echelons of power. This is related to political leadership and the highest courts in a democratic system. The implementation of policies to the extent that a group of dishonest people in power pursue their own interests and harm the interests of voters (Fig. 2).

Fig. 2. Types (kinds) of corruption

Authors Saputra & Saputra (2021) argue that corruption takes various forms: bribery, extortion, dishonest practices, abuse of position and power, and embezzlement. Some of these forms of corruption are common in government agencies, private institutions, organizations, and communities. Most people justify these actions by personal or group interests. However, their actions are criminal and corrupt.

Factors contributing to corruption:

- needs,
- opportunities, and
- rationalization.

Rationalization stands out as an action where the act is wrong or inappropriate, but the perpetrator does not want to be blamed or accused for their actions.

Other factors that encourage corruption:

- greed,
- lifestyle,
- lack of moral values, etc.

According to Suber (2024, p. 66), corruption can be understood as "a synonym for bribery, embezzlement, conflict of interest, or any inappropriate behavior within an organization. Economists have narrowed this definition by conceptualizing corruption as the abuse of public power for private gain. In both cases, these definitions indirectly indicate that corruption involves a shift in the balance of power relations".

The public service sector is one of the most common areas of corruption, and this phenomenon is influenced by low employee salaries, poor internal control or complex administration, and failure to comply with a code of ethics that sets standards of conduct for civil servants based on the principles of anti-corruption, integrity, and transparency (Mahendra et al., 2024). Suramin (2021) argues that corruption is influenced by the abuse of power for personal gain, economic and political factors, moral aspects, and the exploitation of one's position.

Zaksaitė (2024, p. 6) provides the following definition of corruption: it is "a profit-maximizing change through the use (or creation) of an additional (illegal) market. Corruption is treated as a consequence of market imperfection, thus violating free competition and further distorting it through corruption. Individuals act rationally, calculating that under certain conditions they could maximize their personal benefit".

According to Zhang (2024, p. 170), the most common manifestation of conventional corruption is the exchange of power for monetary gain, sometimes referred to as direct power-for-money transactions or the acceptance of bribes to perform certain tasks. According to this author, a new form of corruption is emerging, which is "a facade for traditional corruption, changing the way classic corruption manifests and is presented." The new corruption is "an improved and transformed version of traditional corruption." It is characterized by: concealment of criminal activity, indirect participation, multiple objectives, and the use of advanced technologies.

Cryptocurrency is becoming a new means of bribery and allows corrupt officials to conceal criminal activity, making it more difficult to detect. Courier services used to send gifts and shopping platforms with a "Pay for me" function, which allows others to pay on behalf of the user, are becoming a cover for bribery. Individual officials, when shopping online, receive electronic red envelopes as gifts of gratitude from the recipients of the relevant services, which contributes to bribery. Family corruption is a distinct form of corruption characterized by the involvement of relatives in corrupt activities, the use of power, bribes paid, and the pursuit of personal gain. The subjects of corruption are not only individual corrupt officials who directly accept bribes, but also relatives, family members, and surrounding employees who can accept bribes and conceal corrupt activities between officials and interested parties. Therefore, new forms of corruption are not limited to direct connections, but create numerous intermediate connections (Zhang, 2024).

The concepts of corruption presented by different authors are summarized in the table, which shows that corruption is interpreted differently (Table 1).

Table 1. Concept of corruption (compiled by the authors)

P. C. Kratcoski (2018)	A situation in which a person responsible for specific duties seeks improper or unfair advantage by acting or failing to act as required by his/her position.
K. K. Ibodullaevich and U. G. Kholmomin (2021)	A cause of contradictions with the legal acts and moral norms regulating social life.
F. Saputra and E. B. Saputra (2021)	A criminal act whose actions people justify by personal or group interests, occurring in state institutions, private organizations, and communities.
S. Zaksaitė (2024, p. 6)	A "profit-maximizing change through the use (or creation) of an additional (illegal) market."
D. L. Suber (2024, p. 66)	A "synonym for bribery, embezzlement, conflict of interest, or any improper behavior within an organization."
T. Zhang (2024)	Concealment of criminal acts, indirect participation, multiple goals, and the use of advanced technologies.

In summary, it can be said that there is no universally defined concept of corruption. In the laws of the Republic of Lithuania and in academic literature, corruption is defined as the direct or indirect solicitation, offering, giving, or accepting of a bribe (remuneration, promise, gift), i.e. when a person responsible for performing specific duties within an organization acts dishonestly in exchange for a promise. Forms of corruption include bribery, influence peddling, bribery, abuse of power, illegal registration of rights to property, and failure to perform official duties. Also, the use of advanced technologies (cryptocurrencies, Bitcoin digital currency payments, red envelopes in WeChat groups, the Pay for Me system) to conceal corrupt activities.

Results

This section presents criminal offenses of a corrupt nature, using data collection and systematization methods. The Lithuanian court information system and the public court decision and legislation search system e.teismai.lt were used to find available rulings (decisions) for the period 2020-2025, which allowed for an analysis of the composition of criminal offences of a corrupt nature in the practice of Lithuanian courts (the Supreme Court of Lithuania, Klaipėda and Kaunas Regional Courts). Cases were selected that revealed criminal acts of a corrupt nature under Articles 225-228 of the Criminal Code of the Republic of Lithuania, the characteristics of the crimes, and confirmed or refuted the use of advanced technologies in connection with corrupt activities. Based on the results obtained, general conclusions were formulated.

Corrupt criminal acts in court practice. Digital technologies also have a significant impact on the assessment of evidence in criminal cases. Courts are increasingly dealing with digital evidence, such as electronic payments, social media communications, electronic documents, and financial transaction data. Such data can help to reveal the mechanism of a criminal offense, but at the same time poses new challenges related to determining its authenticity, reliability, and proper procedural assessment.

In addition, digital transformation promotes greater transparency in the work of the courts and better public information. Publicly available databases of court decisions allow for the analysis of court practice, the identification of certain trends, and the assessment of the consistency of court decisions. This contributes to strengthening the principle of the rule of law and increasing public confidence in the court system. At the same time, technological developments also pose new challenges, as the use of digital technologies in criminal activities can make it more difficult to detect and prove them in court proceedings.

An analysis of court practice in 2020-2025 shows that cases deal with issues related to criminal offenses of a corrupt nature (bribery (under Article 225 of the Criminal Code of the Republic of Lithuania), influence peddling (Article 226 of the Criminal Code of the Republic of Lithuania), bribery (Article 227 of the Criminal Code of the Republic of Lithuania), abuse of office (Article 228 of the Criminal Code of the Republic of Lithuania), as well as the reduction and revocation of penalties.

Bribery (Article 225 of the Criminal Code of the Republic of Lithuania). In cases examined in court practice, problematic issues arise regarding the classification of the crime of bribery under Article 225 of the Criminal Code of the Republic of Lithuania. The Supreme Court of Lithuania (in its ruling in criminal case No. 2K-4-511/2025), when deciding on bribery, overturned the previous court ruling and referred the case back for retrial on appeal. In the case, a man was convicted under Article 225(1) of the Criminal Code for being a person equivalent to a civil servant, acting with another person, directly demanding a bribe for his own benefit, promising and agreeing to accept a bribe, and indirectly accepted a bribe for lawful actions in the exercise of his powers. The man agreed to take a bribe for his lawful actions in the exercise of his powers as the head of a polyclinic (i.e. that, in performing his duties as the director of the polyclinic, he selected one company as a partner of the polyclinic to provide public medical services, concluded a service provision contract for services financed by the Territorial Health Insurance Fund, and created conditions for medical specialists at the polyclinic he managed to provide the agreed public medical services on the premises and send patients to the company to receive medical services. In return, he indirectly agreed, through another person, to accept a bribe in the form of money transferred in installments. Later, continuing his criminal activity, the man urged (provoked) the company representative to give a bribe of several thousand euros each month. Later, additional money was agreed upon – for each patient sent to the company. The Supreme Court of Lithuania raised the issue of the different decisions taken by the courts of first and second instance. In the first court's decision, the conversations between the convicted person and the company representative were assessed as not constituting bribery (no bribe was agreed upon, no provocation or encouragement to give a bribe). The conversations were assessed as an opportunity to discuss ways and circumstances of cooperation and the financial success it would bring, therefore it was stated that such conversations with such overall content cannot be artificially criminalized. The Supreme Court of Lithuania noted that it was not at all clear from the judgment of the court of appeal what specific actions of the convicted person the court considered to be a demand for a bribe and what evidence supported this. It was not stated what actions the court considered to be provocation of a bribe. The circumstances of the acceptance of the bribe were also not set out in the circumstances established by the court. According to the court, existing practice shows that an agreement to accept a bribe is considered to be an agreement between the recipient and the giver of the bribe on the time, manner, and place of acceptance of the bribe, joint actions to coordinate and implement the agreement, or other relevant circumstances. When incriminating an agreement to accept a bribe, it is necessary to reveal the essence and content of this agreement, which would correspond to the characteristics of bribery established in Article 225 of the Criminal Code. Provocation to give a bribe is usually recognized as actions where a civil servant or a person equivalent to a civil servant does not openly demand a bribe, but by their actions (inaction) creates a situation where a person, in order to protect their legitimate interests or ensure their implementation, is forced to give a bribe, and it is made sufficiently clear to the person, albeit indirectly, that if the bribe is not given, action will be taken (or not taken) against their interests. A demand for a bribe is usually recognized as actions where a bribe is demanded or even threatened, if the bribe is not given, to perform illegal actions, cause damage to the legitimate interests of a person, or fail to perform legitimate actions that the perpetrator can and must perform in the exercise of his or her powers. A bribe may also be demanded by threatening to perform lawful actions (for example, to initiate a pre-trial investigation or report a criminal offense) if the bribe is not given. The forms of bribery demands may vary; they may be made openly, directly or covertly, through third parties, etc. A bribe demand can only be incriminated if the initiative to give the bribe comes from a civil servant or equivalent person, and not from the bribe giver. If it is established that such an initiative originated from the bribe giver, the demand to give a bribe to a civil servant (or a person equivalent to a civil servant) is not incriminated. The demand to give a bribe must be real (genuine), i.e. related to the genuine intention of the civil servant (or equivalent person) to receive a bribe for their actions or inaction. The case raised questions about criminal intelligence activities (the intelligence measures used were disproportionate because, given the degree of danger and nature of the criminal acts that these persons might have committed, their rights were restricted for a disproportionately long period of time (almost a year) and too intensively, and the criminal intelligence measures were used not only as a means of investigating possible criminal acts, but also as a means of finding evidence of criminal acts in the actions of the person and his accomplice) (Supreme Court of Lithuania ruling of March 6, 2025, in criminal case No. 2K-4-511/2025).

In another case (No. 2K-16-628/2024), the Supreme Court of Lithuania, ruling on bribery, also overturned the previous court ruling and referred the case back for retrial on appeal. According to the case file, the man was convicted under Article 225(1) of the Criminal Code for, as a person equivalent to a civil servant, directly demanding a bribe for his own benefit and accepting it in

exchange for lawful action – favor in the exercise of his powers: he demanded that part of the salary for the additional 0.25 driver position be transferred to him from the drivers of the gymnasium. The man is a person equivalent to a civil servant and works in a public legal entity – a gymnasium as deputy director for economic affairs and has the administrative powers of the school director. The man unlawfully demanded that the drivers give him part of their wages, demanded and accepted a total bribe of €354.78 for his own benefit. In the court's opinion, the man's criminal actions were incorrectly classified under Article 225(1) of the Criminal Code: the circumstances of the case were not properly assessed, contradictory conclusions were presented, and the unlawful instruction to hand over part of the wages in a relationship of subordination cannot in itself be considered bribery. According to the court, it is important to properly reveal the convicted person's intent, i.e., how the man himself perceived the illegal instruction and the money received from employees, which was not done in the case in question. The court of appeal based the man's guilt on how the school drivers perceived (could have perceived) the illegal instruction to transfer part of their wages, namely that they were interested in the favor of their immediate superior, although the drivers themselves did not indicate such circumstances. It was concluded that the conclusions of the court of appeal regarding the convicted person's guilt in demanding and accepting a bribe were unfounded and contrary to the circumstances established in the case.

Trafficking in influence (Article 226 of the Criminal Code of the Republic of Lithuania). In judicial practice, when examining cases of trading in influence, there is a clear intention to influence law enforcement officials by using connections and influence over a civil servant. In Criminal Case No. 2K-83-719/2024 of the Supreme Court of Lithuania, a man was convicted under Article 226(3) of the Criminal Code because he sought to influence another person, using his connections and other likely influence on a civil servant, influence the relevant civil servant to act unlawfully in the exercise of his powers, directly offered, promised, and agreed to give a bribe worth more than 250 MGL to that person. The convicted person sought to have the person to whom the bribe was given influence a judge of the Criminal Division of the Lithuanian Court of Appeal to uphold the appeals of the convicted persons in a certain case, overturn part of the judgment in the case, and acquit the persons. In the case, the court stated that trading in influence is manifested by at least one of the following alternative actions: offering a bribe, promising to give it, agreeing to give a bribe, or giving it. A bribe is offered, promised, agreed to be given, or given for influence on a relevant institution, agency, or organization, a civil servant, or a person equivalent to a civil servant, by taking advantage of one's social position, service, powers, kinship, acquaintances, or other likely influence on them to act or refrain from acting, lawfully or unlawfully, in the exercise of their powers. According to the court, the essence of the prohibition of trading in influence under Article 226 of the Criminal Code is a person's commitment to use (likely or alleged) influence in exchange for a bribe and to influence the relevant institution (institution, organisation) or specific persons with the necessary powers to take a decision of interest to the briber, to perform certain desired actions or, conversely, not to take an undesired decision or not to perform undesired actions. Criminal acts of trading in influence are characterized by direct intent, so it must be established that both the briber and the bribed intermediary were aware of the dangerous nature of their actions and wanted to act in this way. **Bribery** (Article 227 of the Criminal Code of the Republic of Lithuania). In its ruling in criminal case No. 2K-74-594/2024, the Supreme Court of Lithuania, examining a case of bribery, stated that this criminal offense can only be committed with direct intent. In the case, three persons were convicted for giving a bribe with a total value of EUR 1,695.59 (including food products, alcoholic beverages, and three envelopes containing EUR 500 each) to persons equivalent to civil servants for the desired lawful exercise of their powers. They sought to ensure that, in the implementation of the ESO investment project, a decision would be taken to lay an underground electricity cable around the land plot belonging to their company, and that, in the implementation of this project, the underground electricity cable would be laid around the company's land plot. Article 227 of the Criminal Code was applied. The Court of Cassation agreed with the conclusion of the lower courts that one of the convicted persons, who put money into the relevant gift bags in order to achieve certain goals (the favor of ESO employees and his superiors), acted with direct intent, i.e. he was aware that he was giving illegal remuneration to persons equivalent to civil servants – cash for certain actions in the interests of the company. However, attention was drawn to the behavior of the other two company employees, stating that there was no evidence in the case to confirm that these convicted persons were aware that the gift bags also contained money, and therefore there was no direct intent to bribe persons equivalent to civil servants. The Supreme Court overturned the conviction of two company representatives by the court of appeal, leaving in force the part of the first instance court's judgment acquitting them, as no act constituting a crime or criminal offense had been committed. The part of the appellate court's judgment concerning another employee who had given a bribe was also amended, removing the circumstance that the criminal act had been committed as part of a group of accomplices.

The Supreme Court of Lithuania (decision in criminal case No. 2K-281-1073/2024) ruled on a cassation appeal challenging the conviction of a man, M., under Article 227(1) of the Criminal Code and requesting his acquittal, arguing that the court of appeal had unjustifiably found that the convicted person had intentionally attempted to bribe a person equivalent to a civil servant (an emergency medical services (EMS) employee), i.e. to give him a bribe for performing his lawful duties. According to the case file, M. was convicted under Article 227(1) of the Criminal Code because he directly offered and gave a bribe to a person equivalent to a civil servant for the desired lawful action in the exercise of his powers in the following circumstances: after a paramedic and a driver arrived at the scene of the call, examined M. and administered medication, while he was intoxicated (a blood alcohol level of 2.46 was detected), he directly offered a bribe for the desired lawful performance of her duties (i.e., as compensation for administering the medication), and when the employees

refused and were not looking, he gave a bribe of EUR 100 by placing a single EUR 100 banknote in the GMP car between the driver's and passenger's seats. The Supreme Court of Lithuania noted that bribery (Article 227 of the Criminal Code) is objectively manifested by at least one of the following alternative actions: offering a bribe, promising to give it, agreeing to give a bribe, or giving it. The composition of bribery is formal, therefore the criminal act is considered complete from the moment any of the above-mentioned alternative actions are performed. The completion of bribery is not determined by the reaction of the person being bribed, their consent (or refusal) to accept the bribe, the level of understanding of the briber's intentions, or whether the civil servant (or equivalent) being bribed has already performed the desired actions, etc. It is noted that the court of appeal, having assessed the actions of the convicted person in offering and giving a bribe, their intensity and purposefulness, made a reasonable conclusion that the convicted person's behavior was adequate. Although he was intoxicated, the man understood the nature of his criminal act, that he was offering and giving a bribe to a GMP paramedic for administering medication, and he wanted to act in this way. The fact that the convicted person understood his actions as giving a bribe to GMP employees was confirmed by his behavior – calling the Emergency Response Center and telling police officers about giving the bribe. The Supreme Court of Lithuania saw no reason to reach conclusions other than those reached by the court of appeal.

Abuse of office (under Article 228 of the Criminal Code of the Republic of Lithuania) and the criminal acts discussed above. It is relevant to mention the famous MG Baltic political corruption case, in which three individuals were found guilty of bribery (under Article 225 of the Criminal Code of the Republic of Lithuania), influence peddling (Article 226 of the Criminal Code of the Republic of Lithuania), bribery (Article 227 of the Criminal Code of the Republic of Lithuania), and abuse of office (Article 228 of the Criminal Code of the Republic of Lithuania). At the same time, unlawful enrichment (under Article 1891 of the Criminal Code of the Republic of Lithuania) was also proven. The Supreme Court of Lithuania's decision (ruling in criminal case No. 2K-7-119-719/2024) that concluded this case upheld the previous convictions. At the time of the criminal offense, the convicted persons were members of the Seimas of the Republic of Lithuania and abused their public authority for personal gain for themselves, the party they represented, and political and private organizations. This case is complex because different courts issued inconsistent decisions, and some of the information gathered was superfluous, which complicated the work of prosecutors and courts. The complexity was compounded by the fact that bribes were disguised as support and transferred not directly to the legal entities (parties). Many fictitious transactions and connections between legal entities and individuals were created to obscure the true beneficiary and the purpose of the transferred funds (Mastenica, 2024; Zaksaitė, 2024).

According to the case (No. 2K-7-119-719/2024), the court of first instance made an incorrect decision because: it did not analyze and evaluate the circumstances related to the policy pursued by the MG Baltic concern, its operating mechanism, its influence on political processes, specific political parties, and the connections between the persons acquitted in the case; it improperly and selectively assessed the evidence gathered in the case, unjustifiably overemphasizing the testimony of the acquitted persons regarding the content of the recorded conversations and the actions taken by each of them; failed to assess the evidence collected as a whole, did not compare the recorded meetings and conversations with the legislative adoption procedures; did not take into account the interest of individuals in the adoption of the relevant legislation; assessed the actions of individual persons separately from the illegal remuneration received. These aspects prevented the court of first instance from thoroughly examining the criminal case and reaching a fair decision. According to S. Zaksaitė (2024), this extraordinary case dealt with the difference between corruption and bribery, with the court of appeal distinguishing bribery from lobbying. The case "gathered sufficient evidence and revealed sufficient logical connections to conclude that there was a criminally dangerous and clearly illegal relationship of active and passive bribery, rather than merely morally questionable economic and political activity" (Zaksaitė, 2024, p. 10).

The cases examined in court practice reveal instances of criminal acts of a corrupt nature – bribery under Article 225 of the Criminal Code of the Republic of Lithuania, trading in influence (Article 226 of the Criminal Code of the Republic of Lithuania), bribery (Article 227 of the Criminal Code of the Republic of Lithuania), and abuse of office (Article 228 of the Criminal Code of the Republic of Lithuania). In these cases, the convicted persons, being persons equivalent to civil servants, directly demanded bribes for their own benefit and accepted them for lawful actions. Among those convicted of bribery were heads of state institutions, police officers, politicians, and a person who, through an intermediary, intended to give a bribe to a judge for a favorable decision in a criminal case. In most cases, the Supreme Court of Lithuania upheld the decisions of lower courts in its rulings on criminal cases. However, between 2020 and 2025, there were no cases where individuals committing or participating in corrupt activities used advanced digital technologies.

Conclusions

Corruption is understood as a situation in which a person responsible for performing/not performing specific duties seeks an improper or unfair advantage: by performing/failing to perform certain actions, committing offences, abusing their powers and directly/indirectly seeking benefits for themselves/another person. One of the most common areas of corruption is the public service sector. Low employee salaries, poor internal control, and failure to comply with the code of ethics, standards of conduct, and principles of integrity and transparency have a significant impact on the emergence of corruption. The Criminal Code of the Republic of Lithuania regulates the following forms of corruption: bribery (Article 225 of the Criminal Code of the Republic of Lithuania), influence peddling (Article 226 of the Criminal Code of the Republic of Lithuania), bribery (Article 227 of the Criminal Code of the Republic of Lithuania), abuse of office (Article 228 of the Criminal Code of the Republic of Lithuania), illegal registration of rights to property (Article 2281 of the

Criminal Code of the Republic of Lithuania), and failure to perform official duties (Article 229 of the Criminal Code of the Republic of Lithuania). With the continuous development of advanced digital technologies, corruption is also evolving and taking on new forms when advanced technologies are used, giving rise to new types of corruption that are more difficult to detect. The decentralization and anonymity of digital currencies facilitate corrupt activities and provide a cover for bribery.

An analysis of court practice in 2020-2025 in rulings (decisions) on corruption-related offenses shows that criminal acts of a corrupt nature are committed by civil servants in various positions. Law enforcement officials themselves are prosecuted in cases of bribery under Article 225 of the Criminal Code of the Republic of Lithuania, trading in influence under Article 226 of the Criminal Code of the Republic of Lithuania, solicitation under Article 227 of the Criminal Code of the Republic of Lithuania, and abuse of office under Article 228 of the Criminal Code of the Republic of Lithuania. When deciding on corruption cases, courts take into account whether bribery is committed with direct intent, whether the essential elements of a criminal offense are present, and whether the intermediaries being bribed are aware of the dangerous nature of their actions and wish to act in this way. One of the most complex corruption cases is a political one involving the MG Baltic concern, which was concluded in October 2024. In this case, bribes were disguised as support, and recipients were not paid directly, but through fictitious transactions. The individuals were found guilty of bribery, influence peddling, corruption, and abuse of power. Courts of different instances issued inconsistent decisions and interpreted the concept of corruption differently. However, after analyzing court practice in criminal cases of a corrupt nature between 2020 and 2025, it was not possible to identify a single case in which acts of a corrupt nature were committed using advanced digital technologies.

Digital transformation is having an increasing impact on the work of courts and the development of judicial practice. Technological developments are changing both the organization of criminal proceedings and the possibilities for gathering and evaluating evidence. Electronic case management systems, remote court hearings, the use of digital documents, and electronic means of communication make it possible to organize court proceedings more efficiently and increase their speed and accessibility. The court information system operating in Lithuania allows court decisions to be published, making it possible to analyze court practice and thus contribute to greater transparency in the activities of the courts.

Therefore, in order to respond more effectively to possible changes in the phenomenon of corruption, it is advisable to strengthen the capacity to investigate and assess corruption-related crimes in the context of digital technologies, and to pay more attention to the possible use of electronic financial transactions, digital payment instruments, or cryptocurrencies in criminal schemes. It is also important to develop research analyzing the impact of technology on the transformation of corruption and to assess whether existing legal regulations and practices are sufficient to prevent new forms of corruption in the digital environment. Such measures could contribute to more effective corruption prevention and detection in the future. It is recommended to strengthen the competencies of investigators in the field of digital financial technologies and electronic payment systems in order to more effectively identify possible new forms of corruption related to digital technologies. Further research should also be conducted to analyze the interaction between corruption and digital technologies, as technological developments may lead to the emergence of new forms of corruption that have not yet been sufficiently explored in national legal doctrine.

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THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE TRANSFORMATION OF THE LABOUR MARKET: CHALLENGES, OPPORTUNITIES, AND PERSPECTIVES

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Abstract
In recent years, artificial intelligence (AI) has become one of the key drivers of transformation in labour markets and human resource management. Its rapid adoption in organizational practice fundamentally alters work organization, HR processes, decision-making mechanisms, and skill requirements for employees. Beyond efficiency gains, AI increasingly reshapes power relations, job design, and the allocation of responsibilities between humans and intelligent systems. The aim of this study is to analyse the main research directions and thematic areas related to the impact of artificial intelligence on labour markets and human resource management, to identify dominant trends in the academic literature, and to highlight key challenges and opportunities associated with the implementation of AI in HR practices.
Methodologically, the study is based on a systematic literature review conducted in accordance with PRISMA principles and complemented by a bibliometric analysis of publications indexed in the Web of Science and Scopus databases between 2015 and 2025. Relevant studies were selected using a search string combining keywords related to artificial intelligence, labour markets, and human resource management. To identify thematic structures and research clusters, a co-occurrence network analysis of keywords was carried out using the VOSviewer tool. This methodological approach enables a comprehensive mapping of the intellectual structure of the field and allows for the identification of emerging research topics and underexplored areas. The results reveal a significant increase in scientific interest in the analysed topic, particularly after 2020, reflecting accelerated digitalisation of work processes and the rapid development of generative AI technologies. Three main analytical levels of research were identified: the macro level, focusing on economic and institutional impacts of AI on labour markets; the meso level, addressing organisational aspects of AI implementation within firms; and the micro level, concentrating on individuals, changes in skill requirements, wage structures, and human–technology interaction. The analysis further indicates a growing convergence of economic and management-oriented research with legal and ethical scholarship, highlighting the complexity of AI-driven transformation.
A notable finding is the growing emphasis on ethical, social, and regulatory issues, particularly algorithmic fairness, transparency, accountability, and data protection. These aspects are increasingly recognised as critical determinants of trust in AI-supported HR systems and as prerequisites for their long-term acceptance by employees. The study contributes to the systematisation of existing knowledge on the impact of artificial intelligence on human resource management and labour markets and provides a solid theoretical foundation for further empirical research. It also highlights the need for a multidisciplinary approach combining economic, managerial, legal, and ethical perspectives when assessing the long-term consequences of AI adoption in the workplace and its implications for sustainable and inclusive forms of work organisation.
KEY WORDS: artificial intelligence, labour market, literature review, Prisma, WOS
JEL classification: J21, J24, O33

Introduction

The rapid development of artificial intelligence (AI) and automation represents one of the most significant and irreversible trends in contemporary society, with profound implications for the labour market. The labour market is undergoing a transformation that requires not only new skills but also a rethinking of educational policies and human capital development strategies. AI is reshaping both the nature of job positions and the overall employment structure. On the one hand, AI serves as a tool that fosters economic growth and enhances productivity; on the other hand, it raises concerns regarding the disappearance of traditional occupations, the deepening of inequalities, and the consequences of automation.

Emerging jobs that require specialized skills pose challenges for both employees and employers, especially in relation to the need to retrain the workforce and increase the intellectual level of the workforce. In this context, the demand for highly qualified human resources is becoming a central challenge in the labor market. Because a qualified and intellectual workforce contributes to the growth of enterprise efficiency and the sustainability of the enterprise's competitive advantage (Gunaltay & Filiz, 2021).

One of the major advantages of AI lies in its capacity to automate routine and repetitive tasks, thereby enabling workers to focus on more complex and creative activities. At the same time, it can increase productivity and efficiency, especially in sectors where time is a critical factor, such as manufacturing and logistics. Another advantage is the potential to reduce labour costs through the automation of specific tasks, thereby lowering the need for human labour – an aspect particularly relevant in industries with higher wage costs, including healthcare and retail.

AI is also noteworthy for its ability to analyse large volumes of data and to contribute to the development of new products and services. For instance, language translation technologies can facilitate the expansion of companies into new geographic markets. Nevertheless, alongside these undeniable advantages, concerns persist – particularly the threat to existing jobs. It is highly likely that low-skilled positions or jobs involving repetitive tasks will be gradually eliminated. However, adaptation to work

environments shaped by new technologies, combined with the continuous education and upskilling of human resources, will be crucial in ensuring the sustainability of employment in the labour market.

Literature review

Since the late 18th century, the world has experienced several waves of accelerated technological progress, commonly referred to as "industrial revolutions". The First Industrial Revolution, originating in Great Britain, was marked by the invention of the steam engine, which enabled a fundamental shift in production processes. The Second Industrial Revolution, or "technological revolution", emerged nearly a century later in the 1860s with the introduction of electricity and the assembly line. The Third Industrial Revolution, often described as the "digital revolution", began in the 1950s with the spread of digital computers and the rapid development of information and communication technologies (ICT). The term "Fourth Industrial Revolution", coined by Klaus Schwab, is characterized by the widespread adoption of advanced technologies, including AI, the Internet of Things, robotics, and 3D printing (Schwab, 2016). In 2011, the German government launched the strategic initiative *Industry 4.0* to strengthen the industrial sector (Rojko, 2017). As Schwab (2016) notes, each industrial revolution has introduced challenges that societies have had to confront. In this broader context, the question of AI and its impact on labour markets and societies is not new, as technological progress has historically led to the displacement of jobs.

Recent developments in AI are transforming economies and labour markets at an unprecedented pace. This transformation not only demands new skills but also calls for a fundamental rethinking of educational policies and human capital development strategies. Possession of a skilled workforce is recognized as one of the determining factors in the success of enterprises in today's competitive environment, and this can be achieved only with effective management policies and practices (Gunaltay & Filiz, 2021). The nature of work is continuously evolving under the influence of technological progress and innovation.

The impact of AI on employment has become an important theme in the academic debate. Several authors focus specifically on its implications for unemployment (Virgili, 2024; Dall'Anese, 2020; Makridakis, 2017; Kudoh, 2025). Some scholars adopt a pessimistic perspective, warning that AI will largely replace human labour. For instance, Renda (2019), in his publication *Artificial Intelligence*, emphasized the risk of massive job displacement. Others adopt a more balanced view, suggesting that AI adoption does not necessarily lead to higher unemployment, but rather compels workers to adapt to new work environments shaped by digital technologies (Mutascu, 2021; Gries & Naudé, 2018; Abdeldayem & Aldulaimi, 2020). Meister (2019) even argued that AI would ultimately create more jobs than it would eliminate.

Korinek (2023) proposed three possible scenarios regarding the future role of AI. The first envisions AI as a driver of productivity growth and job creation. The second anticipates the emergence of artificial general intelligence (AGI) within two decades, capable of performing all cognitive tasks currently undertaken by humans, thereby fundamentally reshaping the labour market and reducing the role of traditional human labour. The third and most radical scenario foresees the appearance of AGI within as little as five years, leading to large-scale economic and social restructuring.

The growing scholarly attention devoted to AI is reflected in publication trends. For instance, the first Scopus entry on AI dates to 1966 with Jirauch's article *Artificial Intelligence in Automated Design*, which noted that emerging AI techniques at the time were "too remote" to be practically applied. Similarly, the earliest article in WoS linking AI with labour markets appeared in 1994, highlighting the potential of AI to automate production processes in changing manufacturing environments (Yazici et al., 1994).

Aim and Methodology

This study employs bibliometric analysis to examine publications on how artificial intelligence is reshaping the labour market, as well as the opportunities, prospects, and challenges that arise from this transformation. Bibliometric analysis has recently been increasingly applied to identify the characteristics and trends of publications within specific research domains from a quantitative perspective (Mutlu Avinç & Yıldız, 2025). At present, bibliometric analysis is recognized as one of the key methods for evaluating scientific research. The subject of this method is the external characteristics of scientific literature; it investigates the distributional structure, quantitative relationships, and patterns of variation within the body of literature (Xie et al., 2020). Bibliometric analysis enables the assessment of scientific data such as the number of citations and publications, the occurrence of keywords and topics, and related indicators. In this study, bibliometric analysis is applied to publications with the aim of addressing the following central research questions (RQ):

RQ1: Which authors, countries, and institutions have contributed most significantly to the academic debate on artificial intelligence and labor market transformation?

RQ2: How do the most frequently used keywords reflect emerging opportunities, challenges, and perspectives associated with AI-driven changes in employment?

Search Strategy

The search for relevant studies was conducted in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (King et al., 2022). The final search was performed on September 20, 2025. The primary data source used for this analysis was the Web of Science (WoS) database. WoS was selected as the preferred database in this study due to its advanced search and data extraction capabilities, as well as its extensive coverage of scientific publications across diverse topics, categories, and indices (SSCI, SCI-Expanded, AHCI, ESCI, etc.). In recent years, WoS has become the most widely preferred data source among researchers conducting review studies in the field of social sciences (Yan & Zhiping, 2023). To

identify relevant articles in WoS, a search string was constructed by combining keywords aligned with the study's objective and Boolean operators (AND, OR) (Table 1). The search strategy encompassed concepts related to artificial intelligence and the labor market.

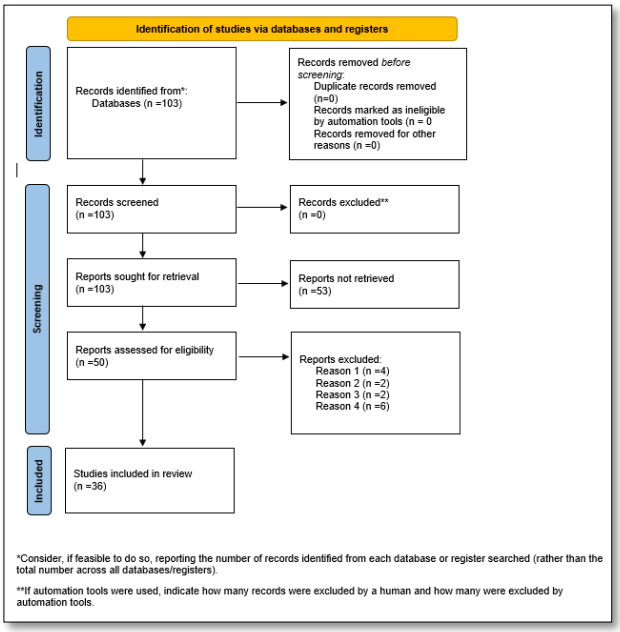

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Table 1. Search string for the identification of relevant studies in the Web of Science (WoS) database

TITLE-ABS-KEY ("artificial intelligence" OR "AI")
AND
TITLE-ABS-KEY ("labour market" OR "employment" OR "job roles" OR "workforce transformation")
AND
TITLE-ABS-KEY ("automation" OR "job displacement" OR "new professions" OR "skill requirements")
AND
TITLE-ABS-KEY ("social inequality" OR "wage disparities" OR "ethics" OR "lifelong learning" OR "education")

The selection process was carried out in several phases (Fig. 1). Figure 1 presents the details of the search and identification procedure. First, the search string was applied in the WoS database, considering titles, abstracts, and keywords. Through this search, 103 potentially relevant documents were identified. Second, duplicate records were removed, and studies were filtered according to the inclusion and exclusion criteria. Only peer-reviewed journal articles and review papers published in English between 2020 and 2025 were considered; publications, books, book chapters, and conference proceedings in languages other than English were excluded to ensure the consistency and academic rigor of the dataset. Third, the selected articles were read, and only those explicitly addressing the impact of artificial intelligence on the labour market were retained. Finally, the eligible documents were organized in an Excel spreadsheet, and the relevant information was systematically recorded. A total of 36 documents were ultimately included in the study.

Table 2. Inclusion and exclusion criteria for the selection of scientific studies

Inclusion criteria	*Exclusion criteria*
Contributions published in 2020 -2025	Contributions outside the time period
Scientific articles, open access conference papers	Empirical works (conceptual articles, editorials, opinions)
Contributions published in English	Contributions not published in English
Documents related to the purpose of our study	Documents unrelated to the purpose of our study

Results and Discussion

The annual distribution and number of publications reflect the overall state of the literature on a given topic, as well as prevailing research trends and the pace of development (Xie et al., 2020). The results of the WoS database search, after applying the exclusion criteria, indicate that publications addressing the impact of artificial intelligence on the labour market began to emerge at the turn of 2018 and 2019. For this reason, the subsequent analysis was temporally restricted to the period from 2020 to September 2025. The average number of documents published annually during this period is six.

Notably, the number of citations of publications concerning the impact of AI on the labour market shows a pronounced upward trajectory through 2024, with this growth trend expected to continue into 2025. The total number of citations recorded amounts to 994 (993 excluding self-citations), with an average of 27.6 citations per item. This upward trend, which began in 2020, continued strongly until 2024 and is projected to remain positive in 2025. Based on the graphical data, it can be concluded that the increasing trend in citation activity within this field – one that has become a particularly important research theme in recent years – is likely to persist.

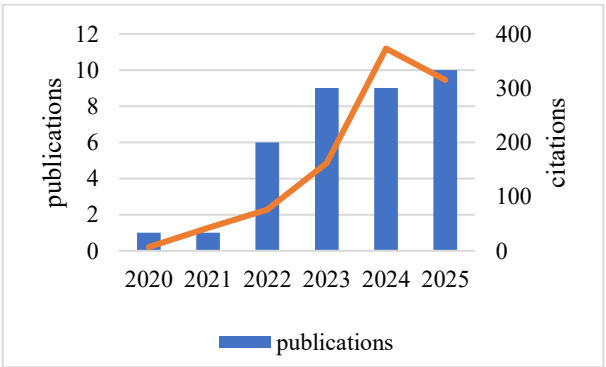

Fig. 2. Times Cited and Publications Over Time

Each journal included in the Web of Science (WoS) Core Collection is assigned to one or more WoS categories. The subject matter and scope of the journal must align with the scope of the WoS categories when such assignments are made. WoS categories are considered an important reference source, as they provide a foundation

for future research and rely on broad classification criteria (Milojević, 2020).

Each journal indexed in the WoS Core Collection is assigned one or more Web of Science categories, with up to six categories possible per journal (Clarivate Support, 2025).

Figure 3 presents the WoS categories of the 35 identified publications in the form of a pie chart. The dominant categories of the articles include Interdisciplinary Social Sciences, Economics, Education and Educational Research, and Management. Other significant WoS categories comprise Industrial Relations and Labor, Multidisciplinary Psychology, Social Issues, Business, as well as Engineering, Electrical and Electronic. These findings indicate that the topic of artificial intelligence and its impact on the labour market represents an interdisciplinary issue that influences diverse areas of both social and economic life.

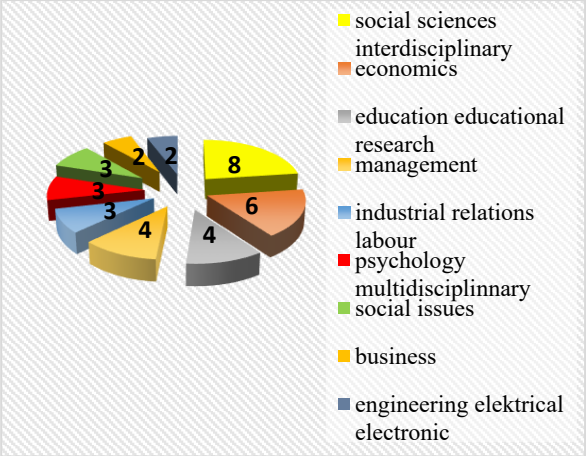

Fig. 3. Web of Science Categories

The number of citations is considered an objective quantitative indicator used to measure the performance and impact of scientific publications, authors, and institutions. Consequently, citation counts are frequently employed in bibliometric analytical studies to reveal the performance of entities within a given field. The citation counts of the top 10 authors who received the highest number of citations in publications on the impact of artificial intelligence on the labour market are presented in Table 3, which also displays the ten most cited countries worldwide.

Table 3. Most cited author and countries/regions

Authors	Record count	Countries/regions	Record count
Chowdhury, S.	12	Peoples China	197
Malik, A.	10	USA	106
Budhwar, P.	7	India	96
Ren S.	7	England	94
Liu Y.	6	Australia	57
Thomas A.	6	Italy	56
Varma A.	6	Malaysia	54
Andalibi N.	4	South Africa	47
Barbosa CE	4	France	44
Chiarello F.	4	Spain	42

When examining citation data from the ten most frequently cited countries, it is evident that China ranks as the most cited country, far ahead of the United States, which holds the second position with 106 citations. Among the ten most cited countries, European nations account for only a 40% share.

The following table (Table 4) presents the five most cited articles. Article citation counts represent the informational output referenced by other publications. Citation analysis enables the determination of how many times a document has been cited by other publications, thereby allowing for an assessment of its impact (Ercan et al., 2025). The journals in which the articles were published, along with their respective indices, are also provided as additional important criteria in evaluating the influence of publications.

The most frequently cited article in this field was published in 2020 and has received a total of 293 citations, with its average annual citation rate ranking as the second highest compared to other articles. The most cited publications discuss topics such as how Industry 4.0 is reshaping workforce requirements, particularly through the growing demand for digital, creative, and interdisciplinary skills. This implies that educational systems must undergo a transformation toward Education 4.0, which encompasses vocational, entrepreneurial, financial, and digital training. The authors highlight that automation leads to the disappearance of routine jobs while simultaneously creating new positions with higher added value (Sima et al., 2020).

Table 4. Most cited publications and author

Publications	Citations		Magazin
	Average per year	Total	Magazin index
Influences of the Industry 4.0 Revolution on the Human Capital Development and Consumer Behavior: A Systematic Review Sima, V; Gheorghe, IG; (...); Nancu, D, (2020)	48,83	293	Sustainability / SSCI
Human resource management in the age of generative artificial intelligence: Perspectives and research directions on ChatGPT Budhwar, P; Chowdhury, S; (...); Varma, A, (2023)	97	291	Human resource management journal/ SSCI
Employment 5.0: The work of the future and the future of work Kolade, O and Owoseni, A., (2022)	25	100	Technology in society / SSCI
The blended future of automation and AI: Examining some long-term societal and ethical impact features Khogali, HO and Mekid, S., (2023)	29,33	88	Technology in society / SSCI
Fostering Graduate Employability: Rethinking Tanzania's University Practices Mgaiwa, SJ., (2021)	6,8	34	Sage open/ SSCI

The article by Budhwar and colleagues provides a multidisciplinary perspective on the impact of generative artificial intelligence (GAI), particularly ChatGPT, on human resource management (HRM) in enterprises. It explains how tools such as ChatGPT are transforming the execution of HR functions, including recruitment, onboarding, performance evaluation, and training. The authors emphasize that while GAI can enhance efficiency in HR processes, it also entails certain risks, such as inaccuracies, biases, ethical dilemmas, and potential job displacement. Moreover, GAI can support sustainable HRM practices (e.g., personalized training, analysis of environmental impacts) but may also exacerbate inequalities (e.g., linguistic, cultural, and gender biases embedded in algorithms) (Budhwar et al., 2023).

The contribution by Kolade and Owoseni provides a systematic review of the scientific literature on the effects of digital transformation on employment and the future of work in the context of Industry 4.0 and Industry 5.0. They describe how skill-biased technological change – where technologies replace routine tasks while simultaneously fostering complex, creative, and social skills among employees – shapes labour market dynamics. They highlight that automation poses a threat to routine jobs. In connection with automation and digitalization processes, new sectors such as the App Economy are emerging, which results in uneven income distribution. The authors conclude that information and communication technologies substantially transform the structure of the labour market, the location of work, and modes of production (Kolade & Owoseni, 2022).

Khogali and Mekid, in their article, analyse concerns related to AI, including fears of identity loss, obsolescence, and alienation among employees. These factors, according to the authors, may hinder the adoption of technologies and reduce their societal benefits. Since AI replaces routine work tasks, it leads to job losses and rising unemployment, thereby necessitating retraining and education for new positions. The authors also emphasize the dehumanization of labour, as employees may feel treated merely as "tools". Monitoring employee well-being in the context of AI applications is therefore crucial, as AI can enhance productivity and flexibility but may also generate stress and uncertainty. Thus, attention to subjective and psychological well-being is essential (Khogali & Mekid, 2023).

Mgaiwa, in his article, examines how universities – particularly in Tanzania – can enhance graduates' employability in the context of high youth unemployment and a rapidly changing labour market shaped by globalization and technology (AI, automation). Many of his findings highlight the weak linkage between universities and employers, resulting in a mismatch between education and labour market requirements. Effective partnerships can improve curricula, internships, research, and consultancy (Mgaiwa, 2021).

Among a total of 26 countries, the leading contributors in terms of publications on how artificial intelligence is reshaping the labour market and the resulting opportunities, prospects, and challenges are the United States with seven publications, the United Kingdom with six, and Spain with four, all of which were included in our analysis.

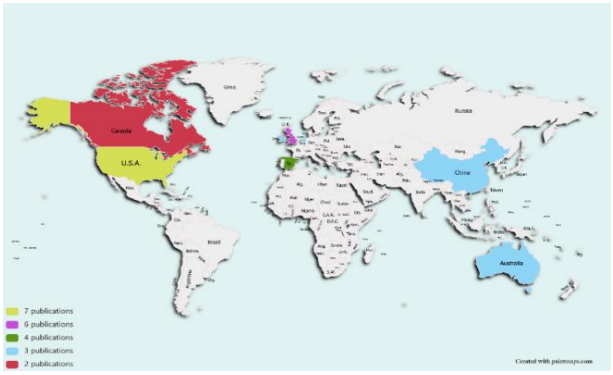

Fig. 4. Map of the most productive countries in the world

Keywords are technical terms that reflect the main content of an article. Keyword analysis helps identify significant and emerging topics within a specific research field (Mutlu Avinç & Yıldız, 2025).

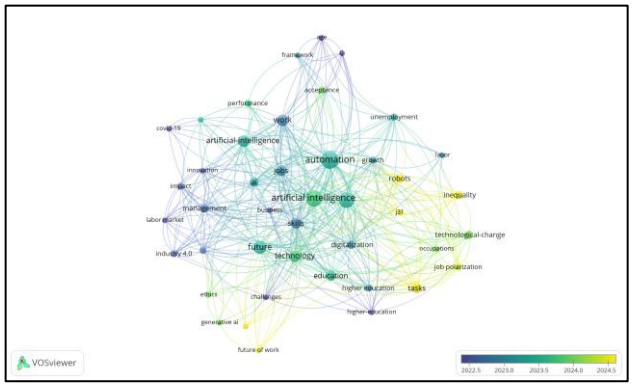

Fig. 5. Visualization of network relationships between keywords with timeline

For this reason, we considered that analysing the occurrence of keywords would be useful for understanding the major themes in publications addressing how artificial intelligence is reshaping the labour market and the resulting opportunities, prospects, and challenges.

The terms artificial intelligence, automation, technology, skill, work, future, and education represent the central concepts in our keyword analysis. Figure 5 illustrates that these keywords are closely interconnected and constitute the foundation of the research domain. Their interlinkages suggest that they are frequently studied together, for example in the context of the application and impact of AI on education, work, and skills. The yellow clusters in the map indicate newly emerging themes (inequality, robots, tasks, generative AI) and possible future research directions. These terms have appeared more frequently in recent publications, suggesting novel research trajectories such as the influence of generative AI and robotics on future work, tasks, and inequalities. Meanwhile, traditional themes such as management, innovation, labour market, and impact (blue clusters) remain important, although research interest appears to be shifting slightly.

Based on the conducted bibliometric analysis, we subsequently evaluated the established research questions.

RQ1: Which authors, countries, and institutions have contributed most significantly to the academic debate on artificial intelligence and labor market transformation?

The bibliometric analysis revealed that the most influential contributions to the academic debate on AI and labor market transformation originate from a limited number of authors, countries, and institutions. Among the authors, Sima et al. (2020), Budhwar et al. (2023), and Kolade & Owoseni (2022) stood out with the highest citation counts, indicating their strong impact on the field. At the country level, China emerged as the most cited and most productive contributor, far ahead of the United States, which ranked second with 106 citations. European countries were represented with only a 40% share among the top ten most cited countries, suggesting that research on this topic remains geographically concentrated. Institutional contributions largely mirrored national trends, with universities and research centers in China, the United States, and the United Kingdom playing leading roles in advancing the debate.

RQ2: How do the most frequently used keywords reflect emerging opportunities, challenges, and perspectives associated with AI-driven changes in employment?

The keyword co-occurrence analysis demonstrated that the terms artificial intelligence, automation, technology, skill, work, future, and education are central concepts forming the backbone of research on AI and the labor market. Their strong interconnections indicate that these topics are frequently studied together, especially in the context of AI's impact on skills, education, and employment structures.

Emerging themes identified through the analysis included inequality, robots, tasks, and generative AI, which were more prominent in recent years. These terms suggest a shift in scholarly attention toward new challenges such as the role of generative AI in shaping job tasks, the potential rise of social and wage inequalities, and the broader implications of robotics for future work. Traditional themes such as management, innovation, labour market, and impact remain relevant but appear to be gradually complemented, if not partially replaced, by more future-oriented research agendas.

Conclusions

The rapid expansion of artificial intelligence (AI) is expected to fundamentally transform industrial sectors and to introduce new challenges for financial decision-makers operating within environmental (Biggi, 2025), social, and governance (ESG) frameworks. Beyond its technological dimension, AI increasingly influences strategic and financial decision-making processes by reshaping how organisations assess risks, measure performance, and allocate resources in line with sustainability objectives. In this context, AI algorithms have emerged as one of the most promising instruments for addressing ESG-related challenges, as they enable the integration of large volumes of generated data with advanced analytical and processing techniques. This combination allows organisations to extract actionable insights, enhance transparency, and support more informed, timely, and efficient decision-making in everyday practice (Burnaev, 2023).

From a research perspective, these developments point to several important research objectives, including the systematic examination of how AI-driven analytics affect the quality and credibility of ESG reporting, the role of AI in mitigating information asymmetries, and its potential contribution to aligning financial performance with environmental and social responsibility. Moreover, there is growing need to investigate the extent to which AI-supported ESG decision-making influences organisational behaviour, stakeholder trust, and long-term value creation across different industries and regulatory environments. Addressing these objectives would significantly advance the understanding of AI as a strategic enabler of sustainable corporate governance.

Another relevant strand of the academic debate concerns the management of AI outsourcing from the perspective of suppliers, encompassing client–vendor relationships, outsourcing contracts, and associated governance mechanisms such as service-level agreements and audit reports (Beulen, 2022). As organisations increasingly rely on external providers for AI solutions, questions related to accountability, risk-sharing, data ownership, and contractual enforcement become central to both operational efficiency and ethical governance. Despite its growing practical relevance, this area remains insufficiently explored in empirical research.

Future research is therefore expected to provide more precise and systematic insights into the economic, organisational, and governance implications of AI outsourcing, including cost–benefit analyses, performance outcomes, and the effectiveness of contractual safeguards. Such research holds considerable potential for informing managerial practice and public policy, particularly in the context of ESG-oriented regulation and responsible AI deployment. By linking technological innovation with governance structures and sustainability goals, this research domain offers a fertile ground for advancing interdisciplinary knowledge at the intersection of artificial intelligence, finance, and corporate governance.

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DEVELOPING A DECISION SUPPORT INTERFACE SOFTWARE FOR PROPERTY VALORIZATION SYSTEM

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Abstract
The real estate industry frequently faces challenges in achieving accurate property valuations, a crucial factor in property transactions. Evaluating commercial real estate tenants is crucial for various stakeholders in the real estate industry, such as property owners, investors, lenders, and property managers. Due to the challenges, this study aims to present a novel Decision Support (DS) software developed to address those challenges by integrating both front-end and back-end systems for seamless, data-driven property assessments. DSS can play a critical role in ensuring accurate property valuations – a key aspect of real estate transactions that often relies on outdated or static data. While the front-end side offers an intuitive interface for users to input property data and receive near-instant results, the back-end side is powered by advanced machine learning algorithms to process this information efficiently. This dual system can ensure that users not only receive accurate valuations but also benefit from a seamless and intuitive user experience. In this paper, we outline the development process, the technologies which we have used, and the evaluation methods which was applied to ensure that the DSS is reliable and effective. The Decision Support System's software for property valorization was developed through comprehensive and multi-stage processes. This system not only enhances the accuracy of valuations but also streamlines the overall decision-making process. The DSS addresses several key challenges in property valuation, including fluctuating market conditions and the complexities of data interpretation. Its scalable design and the continuous learning capabilities of its AI models ensure that the system remains relevant and accurate as market dynamics change. The development of the Decision Support Software (DSS) for property valorization represents a significant step forward in real estate technology. The software's ability to provide accurate, real-time valuations, combined with its user-friendly interface and detailed market insights, positions it as a valuable tool for real estate professionals, investors, and regulators alike.
KEY WORDS: Property valuation, Decision support system (DSS), Machine learning, AI Models, Real estate, Market trends.
JEL classification: R3

Introduction

The DSS software(s) tackles with issues such as fluctuating market conditions and external factors that impact property values. To ensure clarity throughout this paper, the abbreviation DSS is exclusively used to refer to the Decision Support System developed for property valuation. This terminology aligns with its standard usage in decision-making and information systems literature. Any prior reference to "Decision Support Software" or "DS" has been unified under the term DSS for consistency.

By incorporating AI models that continuously learn and adapt, the software improves the accuracy of valuations over time. Furthermore, the decision support system (DSS)'s back-end is built with scalable databases to handle substantial datasets, ensuring its suitability for both small-scale and large-scale property markets. In addition to providing property valuations, a DSS offers actionable insights, making it a comprehensive tool for professionals, investors, and regulators. The software's dual functionality enhances decision-making processes in the real estate market. This paper details the software development process, the materials and methods used, and evaluates its performance, highlighting its potential as a vital tool in modern real estate practices.

Decision Support Systems (DSS) are widely used across various industries to assist decision-makers by analyzing large amounts of data and offering relevant insights. In the real estate sector, DSS can play a critical role in ensuring accurate property valorization – a key aspect of real estate transactions that often relies on outdated or static data. Evaluating commercial real estate tenants is crucial for various stakeholders in the real estate industry, such as property owners, investors, lenders, and property managers (Bytautė, 2024). Traditional valorization methods struggle to account for rapid market changes and the influence of diverse factors such as economic shifts and property characteristics.

In response to these challenges, this study introduces a Decision Support Software (DSS) specifically designed for property valuation. Our DSS integrates both front-end and back-end components to provide users with reliable, real-time valuations. The front-end offers a user-friendly interface that allows easy input of property data and instant access to valorization results. On the back–end, advanced AI models continuously update and refine their predictions based on new data, ensuring that the system remains accurate and reflective of real-time market conditions. This dual system ensures that users not only receive accurate valuations but also benefit from a seamless and intuitive user experience.

DSS which was developed is unique in its ability to combine accurate property valorization with comprehensive market insights, giving users a broader understanding of the real estate landscape. The software is designed to serve real estate professionals, investors, and regulators by providing a flexible, scalable solution that adapts to various market dynamics. Decision support Systems for real estate improve decision-making efficiency in sectors where rapid changes occur. Similarly, Ezenwaka (2025) have argued that AI-powered property valorization systems can revolutionize real estate by providing up-to-date, dynamic assessments. Siddiqui, et. al. (2025) have used comprehensive machine learningbased system for forecasting property prices, highlighting how machine learning enhances predictive accuracy in valorization models. It is explained that decision support systems enhance adaptability in dynamic markets. Yim & Chung (2025) proposed framework that support the responsible and effective integration of AI into property valuation.

In response to these challenges, this study introduces a Decision Support Software (DSS) specifically designed for property valuation. Our DSS integrates both front-end and back-end components to provide users with reliable real-time valuations. The front-end offers a user-friendly interface for easy input of property data, while the back - end utilizes AI models that continuously update and refine their predictions based on market conditions.

Grybauskas, et. al. (2021) demonstrated predictive analytics by a web-scraping algorithm as collecting 18,992 property listings in the city of Vilnius. Al-Rimawi & Nadler (2025) have identified the added value of smart city technologies in real estate development that would transform traditional real estate into smart ones. Root et. al. (2023) developed a data, reasoning, usefulness (DRU) framework for a multi-faceted performance assessment in real estates. McKinsey & Company (2023) have suggested that generative AI techniques can also be integrated to provide more nuanced real estate insights. This dual system ensures that users not only receive accurate valuations but also benefit from a seamless and intuitive user experience.

Our DSS is unique in its ability to combine accurate property valorization with comprehensive market insights, giving users a broader understanding of the real estate landscape. The software is designed to serve real estate professionals, investors, and regulators by providing a flexible, scalable solution that adapts to various market dynamics.

As highlighted by Amannah & Izuchuk (2023), scalable solutions can drive long-term innovation in property management systems. Barlybayev, et. al. (2024) addresses the challenge of accurately determining the fair market value of real estate valorizations in Kazakhistan, ensuring more precise and data-driven decision-making processes. Kumar, et. al. (2019) presents solutions to problems of that designing tools for investment and preserving the privacy of the entire process. Vincenzo et. al. (2019) also discuss the importance of cloud infrastructure for supporting real estate decision-making, noting its critical role in scalability and accessibility. Patel (2023) predicts that the convergence of AI and big data will continue to shape the future of real estate, enabling more sophisticated and data-rich property assessments. The profound impact AI has on property valorization models is explored as highlighting the technological advancements that make these systems more accurate. Kaur & Solomon (2021) stress the aims to examine the extent of property technology, where automation and intelligent systems can optimize property operations and valuations. Liu, et. al. (2025) have found multi-source data fusion and analysis algorithms improving the efficiency of real estate management to emphasize how technological advancements improve the accuracy and efficiency of real estate decision-making.

Belton et al. (2019) discuss the role of AI in smart manufacturing and data privacy, which parallels the growing need for technical standards in real estate technologies. In addition, Che, et al. (2014) explored how intellectual property rights enforcement affects market entry, an issue that is particularly relevant in the development of proprietary real estate technologies. Vallejo-Alonso, et. al. (2015) investigated the financial valorization of intangible assets, a concept that is applicable to the growing field of intellectual property in real estate technology. Finally, Parchomovsky & Siegelman (2002) provide a unified theory of intellectual property, emphasizing the importance of integrating various theoretical perspectives to address contemporary challenges in property valorization and management.

Materials and Methods

The Decision Support System's software for property valorization was developed through comprehensive and multi-stage processes. The tools, methodologies, and technologies used to build and deploy the DSS are described.

Dataset Overview. The Decision Support System (DSS) developed in this study was trained and evaluated using a curated dataset of approximately 16,000 real estate listings collected from Zameen.com, one of Pakistan's leading property platforms. The data was gathered over the course of 2022–2023 and reflects real-time market activity in various urban regions, with a focus on Lahore.

Each listing in the dataset contained key attributes, including the property's location, size (in marlas or square feet), price, number of bedrooms and bathrooms, and property type (e.g., house, plot, apartment). Because the data was sourced from live listings, it offers a genuine representation of actual market dynamics rather than theoretical estimates.

The raw data underwent preprocessing to ensure quality and consistency. This included the removal of duplicate entries, treatment of missing values, standardization of price formats, and the transformation of categorical fields into machine-readable formats. This refined dataset was then used to train and test multiple predictive models aimed at generating accurate property valuations.

Front-End Interface. In this sub-chapter, the software architecture is determined. The DSS is built using a layered software architecture that includes both front-end and back-end components:

Front-End Interface: The front-end was designed with HTML5, CSS3, and JavaScript to create a responsive and

intuitive user interface. React.js was used to manage the interactive components, allowing users to input property data, view real-time results, and access additional market insights. Bootstrap was incorporated for styling, ensuring that the interface is mobile-friendly and accessible across various devices.

The interface is designed to be responsive and intuitive, allowing users to input property data with ease and receive real-time valorization results. Bootstrap was incorporated for styling, ensuring the interface is mobile-friendly and accessible across various devices. The pseudocodes are for the Front-End is given below.

```
function PropertyForm() {
  const [propertyData, setPropertyData] = useState({location: '', size: 0, amenities: ''});
    const handleSubmit = () => {
     fetch('/api/evaluate', {
       method: 'POST',
       body: JSON.stringify(propertyData)
     })
     .then(response => response.json())
     .then(data => console.log(data));
  };
    return (
     <form onSubmit={handleSubmit}>
       <input type="text" placeholder="Location" onChange={(e) => setPropertyData({...propertyData, location: e.target.value})} />
       <input type="number" placeholder="Size" onChange={(e) => setPropertyData({...propertyData, size: e.target.value})} />
       <button type="submit">Evaluate</button>
     </form>
  );
}
START
DISPLAY form with fields: Area (sq. ft.), Bedrooms (BHK), Bathrooms, Location
WAIT for user input
CAPTURE Area, BHK, Bathrooms, Location
IF any field is empty:
  SHOW error message: "Please fill all fields"
  RETURN to form
ELSE:
LOOKUP rate_per_sqft based on BHK and Bathrooms from predefined data
IF rate_per_sqft not found:
SHOW error message: “Invalid BHK or Bathroom count”
    RETURN to form
  ELSE:
    CALCULATE Price = Area * rate_per_sqft
    SHOW estimated price to user
END
```

These pseudocodes can be explained as following lines:

Form Display and Input Capture: The system starts by displaying a form with four fields.

Area (sq. ft.): The size of the property.

Bedrooms (BHK): The number of bedrooms.

Bathrooms: The number of bathrooms.

Location: The geographical location of the property.

It waits for the user to input these values.

Validation of Input Fields: Checks if any of the fields are empty.

If a field is empty, the system prompts the user with an error message: "Please fill all fields" and returns the user to the form for correction. This ensures that the input data is complete before proceeding.

Lookup Rate Per Square Foot: Based on the BHK (bedrooms) and Bathrooms, the system looks up a predefined dataset for the rate per square foot (rate_per_sqft). If the rate for the given combination of BHK and Bathrooms is not found, it shows an error: "Invalid BHK or Bathroom count" and returns to the form.

Price Calculation: If valid data is found, the price is calculated using the equation 1.

$$Price = Area\ (sq.ft.) Xrate\ per\ sq\_ft \quad (1)$$

Display Result: The calculated estimated price is displayed to the user. Example: “The estimated price of your property is: ₹XXXXXX”

End: The process terminates once the price is displayed.

Figure 1 shows the Front-End Interface when the codes are compiled.

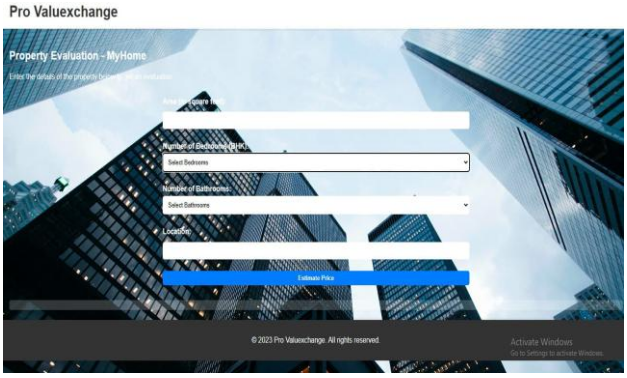

Fig. 1. Front-End Interface

In the Figure 1, the interface of a property valorization platform is illustrated titled as “MyHome”. The design allows users to input details such as property area, the number of bedrooms (BHK), bathrooms, and the location to estimate the property's price. The interface features a clean layout with dropdowns, selection buttons, and a prominent “Estimate Price” button for functionality

Property valorization process: The property valorization process involves determining the value of a property based on various factors such as market trends, location, and condition. In traditional methods, data collection is done through physical property inspections

and market comparisons, followed by subjective analysis to estimate value. This process relies on historical data and lacks real-time updates. On the other hand, AI-powered property valorization leverages machine learning models and real-time data integration to predict property values more accurately and quickly. It collects and processes large datasets, continuously improving predictions by learning from new data, offering detailed insights into market trends and future projections. AI systems scale efficiently and provide faster, more accurate valuations compared to traditional methods.

Back-End Processing: The back - end was developed by using Python and the Flask framework. Flask was chosen for its flexibility and lightweight nature, making it ideal for handling API requests and managing the data flow between the front-end and the AI models. Python's extensive library support for machine learning models, like Scikit-Learn and TensorFlow, made it the optimal choice for building the valorization algorithms. Flask handles user inputs, processes property data, and communicates with the machine learning models, producing accurate property valuations in real-time. The back - end is responsible for processing user inputs, managing property data, and running the machine learning models that produce the valuations. The codes are for the Front–End are given below.

for the Back – End are:

```
from flask import Flask, request, jsonify
import pickle
app = Flask(__name__)
# Load the trained model
model = pickle.load(open('model.pkl', 'rb'))
```

Figure 2 shows the comparison of property valorization processes.

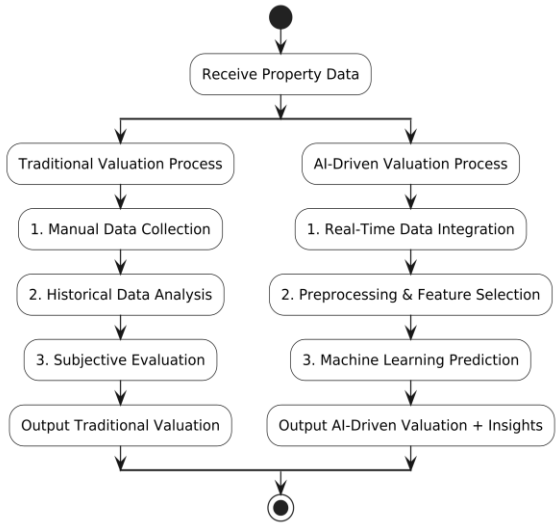

Fig. 2. Property Valorization Process

In the Figure 2, two approaches to property valorization are compared: the AI-driven Decision Support System (AI_DSS) and the traditional method. The AI_DSS leverages machine learning models to provide real-time valuations, insights, and analytics, while the traditional approach relies on manual evaluation using historical data, offering limited insights. Both approaches incorporate user feedback to refine the process, but the AI_DSS stands out for its efficiency and advanced analytics.

The AI-Driven Decision Support System (AI_DSS) is designed to provide real-time property valuations using advanced machine learning models. Figure 2 compares the AI_DSS with traditional property valorization methods, highlighting its advantages in terms of accuracy, scalability, and real-time insights.

This section details the back-end interface implementation, which serves as the core of the AI_DSS. It handles API requests, preprocesses input data, and generates property valuations using the trained machine learning model. The pseudocodes are for the Back-End Interface are given below lines.

```
# Flask route to handle property valorization requests
@app.route('/api/evaluate', methods=['POST'])
def evaluate():
 """
 Handles API requests for property valuation.
 Input: JSON data containing property details (e.g., area, location, BHK, etc.).
 Output: Predicted property valuation.
 """
 Step 1: Receive input data in JSON format
 data = request.get_json()
 Step 2: Preprocess the input data for the machine learning model
 processed_data = preprocess(data)
 Step 3: Use the trained machine learning model to predict valuation
 prediction = model.predict([processed_data])
 Step 4: Return the predicted valorization as a JSON response
 return jsonify({'valuation': prediction[0]})

Entry point for running the Flask application
if __name__ == '__main__':
# Step 5: Start the Flask server in debug mode for development
app.run(debug=True)
```

Explanation of these pseudocodes are being done as following lines:

Route Definition: The back-end defines an API endpoint (/api/evaluate) that accepts HTTP POST requests. This endpoint processes user input for property valuation.

Input Handling: The data = request.get_json() statement retrieves property details (e.g., area, location, number of bedrooms, and bathrooms) in JSON format. This structure ensures compatibility with web or mobile applications.

Pre-processing: The preprocess(data) function standardizes input data. This includes:

Handling missing values, encoding categorical features (e.g., location), and scaling numerical values to match the machine learning model's requirements.

Prediction: The trained machine learning model (model.predict) estimates the property valorization based on the processed data. This model leverages AI to generate real-time and accurate predictions.

Response Generation: The predicted valorization is returned to the front end in JSON format ({'valuation': prediction[0]}), making it easy to integrate into a web or mobile interface.

Server Execution: The Flask application is launched in debug mode, allowing developers to test and refine the back-end interface.

Below Figure 3 shows the Back-End Interface when the codes are compiled.

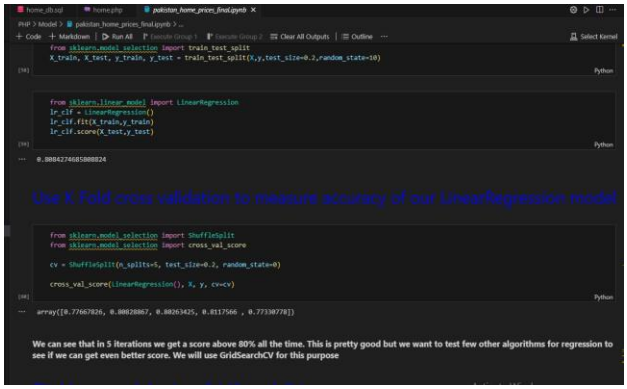

Fig. 3. Evaluating Linear Regression Model with K-Fold Cross Validation

The machine learning models used in this study were evaluated by using K-Fold Cross Validation to ensure generalizability. We implemented a ShuffleSplit strategy, randomly dividing the dataset into training and testing subsets across five iterations. In each fold, 80% of the data was used for training and 20% for testing. The R^2 scores achieved across the folds consistently ranged between 0.77 and 0.81, suggesting stable and reliable predictive performance of the regression model.

Evaluating Linear Regression Model with K-Fold Cross-Validation: To ensure the reliability and robustness of the Linear Regression model, K-Fold Cross-Validation is applied using the ShuffleSplit method. This approach divides the dataset into multiple training and testing sets, allowing the model to be evaluated on different data splits, ensuring unbiased performance metrics.

Code Implementation: The following code demonstrates the process of evaluating the Linear Regression model using K-Fold Cross-Validation with ShuffleSplit:

```
from sklearn.model_selection import ShuffleSplit
from sklearn.model_selection import cross_val_score
# Configure ShuffleSplit for K-Fold Cross-Validation
cv = ShuffleSplit(n_splits=5, test_size=0.2, random_state=0)
# Evaluate the Linear Regression model:
from sklearn.linear_model import LinearRegression
cross_val_score(LinearRegression(), X, y, cv=cv)
Output:
array([0.77667826, 0.80828867, 0.80263425, 0.8117566, 0.77330778])
```

Explanation of these pseudocodes are being given as following lines.

Cross-Validation Configuration: The ShuffleSplit method is used to create 5 random splits (n_splits=5) of the dataset, with 80% of the data used for training and 20% for testing (test_size=0.2).

A fixed random seed (random_state=0) ensures the reproducibility of the data splits.

Model Evaluation: The **cross_val_score** function evaluates the Linear Regression model on each train-test split, computing the R^2 score for each fold.

The R^2 score measures how well the model explains the variance in the target variable, with higher values indicating better performance.

Results: The output is an array of R^2 scores for the 5 folds:

Fold 1: 0.7767
Fold 2: 0.8083
Fold 3: 0.8026
Fold 4: 0.8118
Fold 5: 0.7733

The scores are consistently above 0.77, demonstrating the model's reliable performance.

Significance of K-Fold Cross-Validation: K-Fold Cross-Validation is a critical step in evaluating machine learning models. It provides a robust measure of performance by:

Reducing Bias: Ensures the evaluation metric (R^2) is not influenced by a single train-test split.

Improving Reliability: The average score across folds reflects the model's ability to generalize to unseen data.

Detecting Overfitting: Highlights if the model performs poorly on certain test sets, indicating potential overfitting or underfitting.

In the Figure 3, the use of the LinearRegression model from Scikit-learn to evaluate its accuracy through K-Fold cross-validation is demonstrated. It highlights the implementation of ShuffleSplit to create five iterations with an 80%-20% train-test split, resulting in consistent scores above 80%, indicating the model's reliable performance.

The dataset is split into 5 folds, with 80% for training and 20% for testing in each iteration. The R^2 scores across all folds are consistently above 0.77, indicating a reliable and well-performing model. The use of cross-validation ensures that the model's performance is not biased and reflects its ability to generalize to new data. This method highlights the robustness of the Linear Regression model in the AI-Driven Decision Support System (AI_DSS), validating its suitability for real-time property valorization tasks.

Database management. A MySQL database was implemented to store property data, user information, and transaction records. MySQL was selected due to its ease of integration with Python and its ability to scale according to the demands of the system. The database schema was designed to handle large datasets efficiently, providing fast access to property data and ensuring the integrity of all stored information. Database Schema Example pseudo codes are writtnn below lines.

```
CREATE TABLE properties (
id INT AUTO_INCREMENT PRIMARY KEY,
location VARCHAR(255),
size INT,
amenities TEXT,
market_value DECIMAL(15,2)
);
```

These codes are executed as explained below: The system's back-end incorporates a structured MySQL relational database designed to handle property listing information efficiently. The database schema includes fields for property ID, title, location, price, area, and features such as the number of bedrooms and bathrooms. The schema is normalized to support fast queries and smooth integration with the prediction model. It also ensures data integrity and scalability for potential future expansion.

When the SQL database management interface is obtained, it enables efficient management of tables such as users, properties, and saved data, while offering functionalities like running queries, managing privileges, and creating new tables essential for the platform's backend operations.

AI models and machine learning insertion. At the core of the DSS's valorization engine are machine learning models developed using Scikit-Learn and TensorFlow. These models were trained on historical property data, including market trends and economic indicators.

The primary models used were regression models for predicting property values, but additional models like random forests and neural networks were employed to enhance the accuracy and adaptability of the system. The AI models continuously improve by learning from new data, ensuring that the system remains up-to-date and accurate as market conditions evolve. In the following, how to collect data and to reprocess the data are explained.

Data Collection and Preprocessing: The data used in the development of the DSS is sourced from various public records, real estate listings, and market reports. The data is preprocessed to ensure it was clean and ready for use in the machine learning models. These processes are data cleaning, normalization, and feature selection.

Firstly, the data is stripped of duplicates, incomplete entries are handled, and inconsistencies are corrected. Secondly, numerical data is normalized to ensure consistency across different property attributes, allowing the models to process the data efficiently. Then, key features that impact property valuations, such as property location, size, amenities, and local market trends, are selected for inclusion in the models.

Now, how to test and to validate the system are going to be explained. To ensure the system was reliable and accurate, we have conducted several rounds of testing. They unit testing, integration testing and user acceptance testing (UAT).

Each individual component of the software is tested in isolation to verify its functionality. The entire system, including the front-end, back-end, and database, is tested to ensure all components worked together seamlessly. A group of real estate professionals and potential users are invited to test the software and provide feedback on its usability and performance. The task order is being come to deploying the DSS on a local server. The pseudocodes for the Regression Model are presented below lines.

```
from sklearn.linear_model import LinearRegression
model = LinearRegression()
model.fit(X_train, y_train)
predictions = model.predict(X_test)
```

Equations below are given for Mean Imputation and One-Hot Encoding as shown in equations 2 and 3.

$$Value_{imputed} = \frac{1}{n}\sum_{i-1}^{n} x_i \quad (2)$$

$$Encoded\ Value = \begin{cases} 1 & if\ category \\ 0 & otherwise \end{cases} \quad (3)$$

where – Eq. 2 shows, missing values were handled using mean imputation, Eq. 3 shows categorical variables were encoded using one-hot encoding.

Eq. 2 represents the method used to handle missing numerical data in the dataset. By replacing missing values with the mean of the corresponding feature, the dataset remains consistent and complete. This ensures that no data is lost due to missing entries, which could otherwise introduce bias or inaccuracies into the AI model's predictions.

Eq. 3 illustrates the process of encoding categorical variables into binary vectors. Each category is represented as a unique binary value (1 or 0). This transformation is essential because most machine learning models, including those in the DSS, require numerical inputs. One-hot encoding ensures that categorical data is accurately represented and effectively utilized during training.

The Decision Support System employs advanced preprocessing techniques to prepare data for AI-driven property valuation. Missing numerical values are addressed using mean imputation, as described in Eq. 1, ensuring consistency across the dataset. Additionally, categorical variables are transformed into binary vectors through one-hot encoding, as outlined in Eq. 2, facilitating seamless integration with machine learning algorithms. These preprocessing steps enhance data quality and contribute to the system's overall accuracy and reliability.

Deployment on Local Server and Workflow Procedures. As the DSS has not yet been launched for public use, it is currently deployed on a local server for internal testing and refinement. The local server setup ensures that the development team can thoroughly test the system before a full launch. The Flask application runs locally, with the system accessible via a local network (e.g., localhost:5000). This setup allows for controlled testing of all system features. The MySQL database is also hosted locally to ensure that all data remains within the internal testing environment.

Docker containers are used for managing the deployment, ensuring consistency across different development, and testing environments. Once the internal testing phase is complete, the DSS will be deployed to a cloud platform for wider public use, with potential options including AWS for scalability and high availability.

This chapter outlines the procedural steps for deploying the AI-Powered Decision Support System (DSS) for

property valuation. It details the necessary prerequisites, setup instructions, and steps to run the system locally.
Prerequisites: Before starting the deployment process, ensure that the following tools are installed. It is ensured that Python 3.8 or higher is installed. Python's package manager is necessary to install dependencies. It is verified by using the command.
pip --version

Git: Required for version control and to clone the project repository. Download from the official. Steps for Deployment are as following.

Clone the Repository: Open a terminal or command prompt. Use the following command to clone the repository.

git clone <repository-url>

cd <repository-name>

Set Up the Virtual Environment:

Create a virtual environment by running:

python -m venv venv

On Windows, use:

venv\Scripts\activate

install Required Packages:

Ensure you are in the project directory and the virtual environment is activated. Install dependencies by running:

pip install -r requirements.txt

load the Dataset:

Place the zameen**.**csv file in the data directory within your project folder. Ensure that the file path in the code points to the correct location of the dataset.

Train the Model: Run the script to process the dataset and train the model

python train_model.py

his script will process the data, train the model, and save the trained model for further use.

Run the Web Application: To start the web application, execute the following command:

python app.py

Access the Application:

Open a web browser and navigate to http://127.0.0.1:5000

The application will be accessible for interaction.

While Figure 4 shows system components and deployment diagram, on the other hand Figure 5 displays state diagram: AI-Powered DSS workflow.

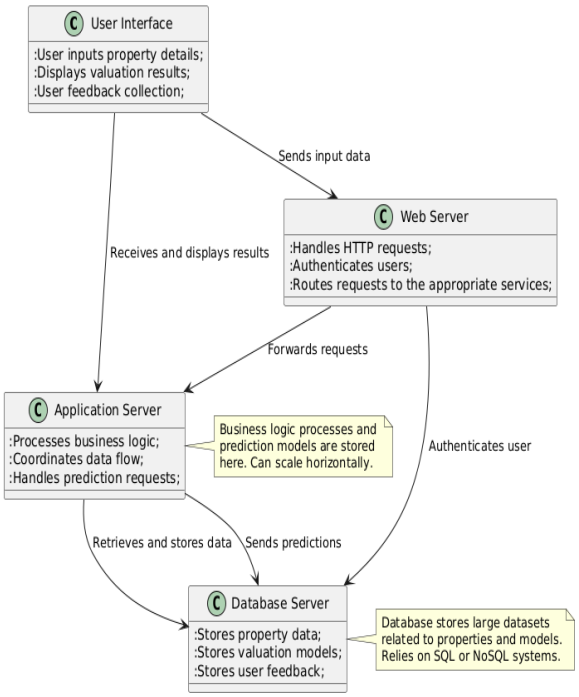

Fig. 4. System components and deployment diagram

In Figure 4, the system's architecture is showcased. It illustrates how various components interact in the property evaluation platform. It highlights the user interface, web server, application server, and database server, along with the communication protocols ensuring seamless data flow and model deployment.

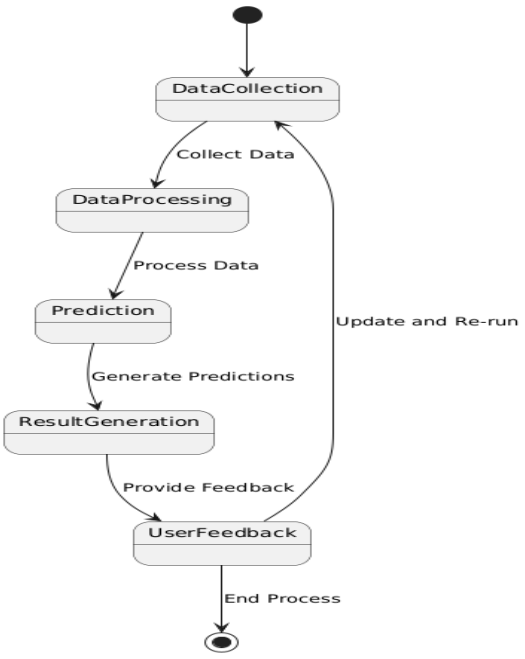

Fig. 5. State diagram: AI-Powered DSS workflow

The internal workflow of the DSS follows a logical progression. Users begin by submitting property information through a form-based interface. This input is then passed to a data preprocessing module, which formats and validates the entries before sending them to the trained machine learning model. The prediction engine processes the data and returns an estimated property value. The system presents the result back to the user in an accessible format, possibly accompanied by a valorization range and relevant market insights. A feedback mechanism is included to support ongoing improvements based on user interaction and new data inputs.

When the workflow of the AI-powered Decision Support System (DSS) for property evaluation is outlined, it captures the system states, from inputting property details to processing with machine learning models, generating valuations, and handling user feedback for continuous improvement. This State Diagram illustrates the main workflow for generating property valuations in the AI-Powered DSS. It starts with Data Collection, followed by Data Processing, Prediction, and finally Result Generation, where the user provides feedback, and the process can end or be repeated.

GARNING is a development server. It shall not be used in a production deployment. For product deployment, a production 55 server is used instead. It is being run on htts://127.0.0.1:5000

Market trends. The real estate market is undergoing significant transformation due to the integration of technology, driven by advancements in data analytics, artificial intelligence (AI), and digital platforms. Current utility trends include Data-Driven Decision Making, Digital Property Platforms, AI and Machine Learning, in real estate.

Property valorization is increasingly reliant on real-time data analytics, integrating property attributes, market demand, and economic indicators. This allows for more accurate assessments and risk analysis. These platforms improve transparency and streamline market interactions. Machine learning models are being used to predict market trends, optimize pricing, and identify investment opportunities. AI tools also assist in understanding buyer preferences and forecasting demand. VR and AR are being adopted for virtual property tours, which help buyers explore properties without physical visits, especially in the post-pandemic era. Blockchain technology is being explored for secure property transactions, reducing fraud, and enhancing the reliability of property records.

The Decision Support System (DSS) for property valorization has the potential to impact the real estate market. The DSS model utilizes machine learning algorithms and real-time data integration to provide highly accurate property valuations compared to traditional methods. This reduces discrepancies and enhances market confidence. By analyzing historical and current market data, the DSS can generate actionable insights, helping stakeholders make informed decisions. Automated processes in DSS models reduce the need for manual assessments, saving time and operational costs for real estate professionals. The DSS provides a consistent framework for property evaluation, addressing subjectivity and variation in traditional manual methods. By offering instant property evaluations and market analysis, the DSS supports real-time decision-making for buyers, sellers, and investors. In Pakistan, the real estate market is undergoing a transformation driven by data-driven decision-making and the growing use of digital platforms for property listings and transactions. However, the adoption of AI and machine learning in real estate is still in its nascent stages, with limited integration into property valuations and market forecasting. Despite this, the rise of online property portals such as Zameen.com and OLX is facilitating transparency by providing real-time property data, making the market more accessible for buyers and sellers. Additionally, blockchain technology is gradually gaining attention for its potential to secure property transactions and improve trust in property documentation. The Table 1 makes an impact comparison amongst the current trends and the developed DSS.

Table 1. Impact comparison of current trends and DSS

Feature	Current Utility Trends	Current Utility Trends
Valorization method	Primarily historical data with manual insights	AI-driven real-time property valuation
Accuracy	Subject to human error and market volatility	Highly accurate with reduced margin of error
Speed	Time-consuming manual processes	Instant analysis and valuation
Market Insights	Limited to historical and static data	Dynamic and predictive market insights
Accessibility	Requires professional expertise	Accessible via user-friendly interfaces
Transparency	Moderate, influenced by subjective evaluations	High, with clear and consistent results
Feature	Current Utility Trends	Current Utility Trends

The integration of the DSS model aligns with the current technological evolution of the real estate market while offering improvements in accuracy, efficiency, and decision-making capabilities. By addressing the limitations of existing trends, the DSS has the potential to reshape property valorization and market analysis practices, ensuring a more streamlined and data-driven approach.

Results and Discussion

The Decision Support System software developed for property valorization yielded promising results in terms of both accuracy and user satisfaction. The following sections will discuss the outcomes of the system's performance testing and the broader implications for real estate decision-making.

Accuracy of Valuations: The machine learning models embedded in the DSS produced highly accurate property valuations, with an average error margin of less than 5%. This level of accuracy marks a significant improvement over traditional valorization methods, which tend to rely on static data and generalized formulas. The ability to incorporate real-time market data and continuously update the models ensured that the valuations were aligned with current market trends.

DSS is compared with the traditional methods as shown in Figure 6. Figure 7 shows UML diagram. This

UML diagram illustrates the structure of the property evaluation system, showcasing relationships between key components like user interface, ML model, database, and valorization services. It visually represents how these components interact to fulfill the system's functionality.

One of the key advantages of the DSS is its ability to contribute to market transparency. By offering clear, data-driven property valuations and market insights, the software reduces information asymmetry, which is often a problem in real estate transactions. The transparency provided by the DSS can lead to more informed decision-making, fairer property pricing, and a reduction in disputes over property values.

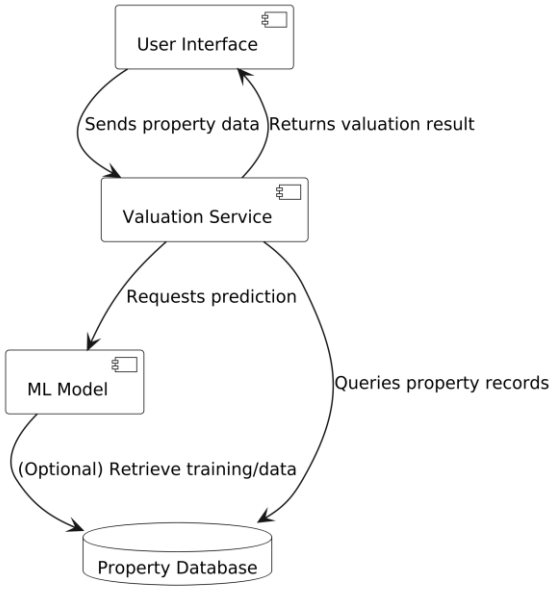

Fig. 6. Architecture of an AI-Powered Decision Support System for Property Valuation

The DSS performed well during stress testing, with the system handling large volumes of data and multiple simultaneous user requests without significant delays. This is due to the efficient database management system and the potential for cloud deployment in the future. The ability to scale the software to accommodate increased demand makes it suitable for use in both local real estate markets and larger, more competitive environments.

Despite the positive results, several challenges and limitations were identified during the development and testing of the DSS. The accuracy of the AI models depends on the quality of the data used for training. In cases where the input data was incomplete or inconsistent, the system's performance suffered.

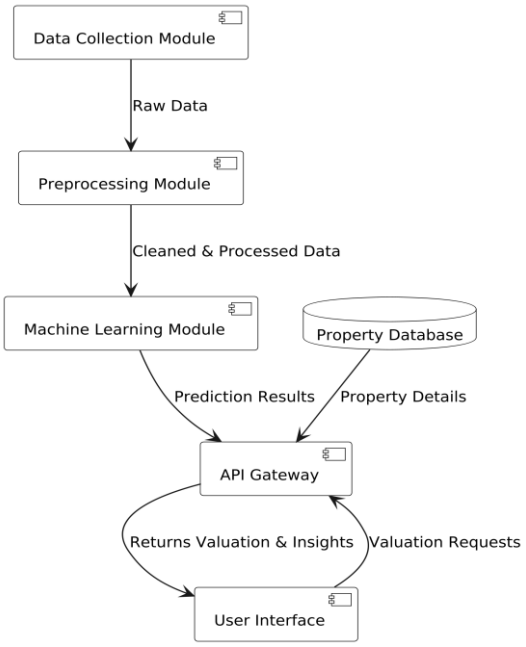

Fig. 7. Component diagram: System architecture

As more complex machine learning models were introduced, they required greater computational resources, which could impact the system's responsiveness. Figures 8–9 show the system's performance during stress testing and the scalability of the AI models, demonstrating the system's ability to handle large datasets and provide real-time property valuations even under heavy user loads.

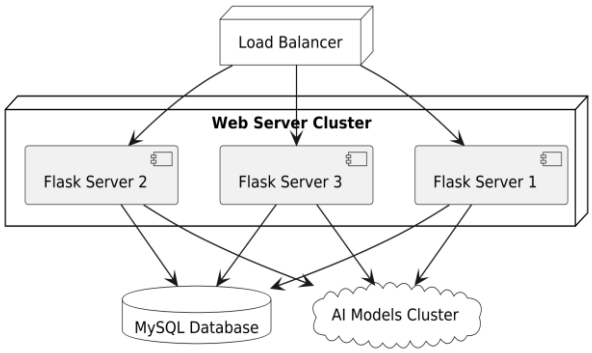

Fig 8. Component Diagram: System Architecture

In the Figures above the AI-Powered DSS architecture and the flow between different system components such as Frontend, Backend (Flask), Database (MySQL), and API are visualized. The Machine Learning Models are part of the backend, and the system retrieves property data from the Database. Table 2–6 exhibit property data attributes, valorization results, model predictions, comparative analysis, historical trends, and user feedback metrics.

Table 2. Advantages and Limitations of DSS AI Models

Model Type	Advantages	Limitations	References
Linear Regression	Simple, fast, and interpretable	Assumes linear relationships, limited for complex patterns	Root et. al., 2023
Random Forest	Handles non-linear data, reduces overfitting	Requires more computational power, complex to interpret	McKinsey& Company, 2023 Patel, 2023
Neural Networks	Powerful for capturing complex, non-linear relation-ships	High computational requirements, can be a "black box"	Siddique, et. Al. (2025) McKinsey& Company, 2023
Combined Models	Leverages multiple algorithms for better accuracy	More difficult to implement and optimize	Kumar, et. al. 2019

Table 3. DSS Performance Metrics and User Feedback

Metric	DSS Performance	Traditional Methods	References
Response Time	<1 second	2–5 minutes	Patel, 2023
User Satisfaction	92% positive	55% positive	Kumar, et. al. 2019
Data Scalability	1 million records	Limited to 10k records	Patel, 2023 Kaur and Solomon, 2021
Accuracy	95% (AI models)	70% (manual methods)	Siddique, et. al. (2025), McKinsey& Company, 2023

The Table 2 outlines the strengths and weaknesses of AI models in DSS, helping users understand trade-offs in computational efficiency and adaptability.

The Table 3 summarizes key metrics like response time, user load handling, and database scalability. The DSS demonstrates robustness in managing high volumes of data while maintaining quick processing times. Also, showcasing the comparison between user satisfaction for DSS and traditional methods in terms of ease of use, speed, and transparency. DSS receives high ratings for its intuitive design and detailed insights.

Table 4. Comparison of DSS and Traditional Property Valorization Methods

Feature	Proposed DSS (AI-Powered)	Traditional Methods	References
Real-Time Data Integration	Yes, continuously updates with market changes	No, relies on historical data	Vallejo-Alonso et al., 2023
Machine Learning Integration	Regression, Random Forest, Neural Networks	No AI integration	Belton et al., 2019 Parchomovsky and Siegelman, 2002
Data Processing	Handles large datasets efficiently with real-time analysis	Struggles with large datasets, leading to slower processing	Che et al., 2014
User Experience (UX)	User-friendly, interactive front – end with instant feedback	Often lacks user interfaces, or uses outdated systems	Vallejo-Alonso et al., 2023
Scalability	Highly scalable for large, growing datasets	Limited scalability for large datasets	Belton et al., 2019 Che et al., 2014
Market Insights	Provides detailed insights including economic trends and analytics	Limited to basic property price calculations	Parchomovsky and Siegelman, 2002
Cost Efficiency	High initial development cost but efficient in the long run	Higher operational costs due to manual updates	Vallejo-Alonso et al., 2023

The Table 4 highlights how DSS excels in accuracy, data processing, and insights compared to traditional methods. The DSS demonstrates continuous updates with market changes, handles range datasets, provides detailed insights, providing also user-friendly interactive user experience, while traditional methods on the other hand struggle, lack or have limitations for same features.

Table 5. Detailed System Test Results for DSS

Unit Testing	Components Tested	Outcome	Notes	References
Integration Testing	Front-End React Components, API Endpoints	Passed all component-level tests	No major issues detected, all unit's function as expected	Kumar, et. al. 2019

Stress Testing	Front-End to Back-End, Back-End to Database Database handling with high user traffic	Smooth data flow between components, no data loss. Handled 500 concurrent users with <1s response time.	Seamless communication between all layers. Efficient database query processing, no bottlenecks	Vincenzo et. al., 2019 Barlybayev, et. al, 2024
Scalability Testing	Back-End (Flask + Python) and Database	Scaled to 1 million records with negligible performance loss	Flask handled high load well, MySQL scaled appropriately	Barlybayev, et. al, 2024 Hand and Li, 2023
Security Testing	Vulnerability checks on API endpoints	Passed penetration testing and data security standards	No critical vulnerabilities, encryption methods validated	Mc Kinsey & Company, 2023 Patel, 2023
User Acceptance Testing	Real Estate Professionals and Investors	Positive feedback on usability, functionality, and insights	Users found the UI intuitive and insightful for market analysis	Kumar, et. al. 2019

Table 5 summarizes system testing results, validating the robustness and scalability of the DSS. The detailed system results showcasing the positive feedback on usability and insights by real estate professionals, no critical vulnerabilities, seamless communication between the layers, analyzing testing results of different units.

Conclusion

The development of the Decision Support Software (DSS) for property valorization represents a significant step forward in real estate technology. The software's ability to provide accurate, real-time valuations, combined with its user-friendly interface and detailed market insights, positions it as a valuable tool for real estate professionals, investors, and regulators alike. The DSS addresses several key challenges in property valuation, including fluctuating market conditions and the complexities of data interpretation. Its scalable design and the continuous learning capabilities of its AI models ensure that the system remains relevant and accurate as market dynamics change.

Looking ahead, we aim to expand the system's capabilities by incorporating more advanced AI models and integrating additional data sources. These improvements will not only enhance the performance of the DSS but also contribute to greater transparency and efficiency in real estate markets around the world.

The development of the Decision Support Software (DSS) for property valorization represents a significant step forward in real estate technology. The software's ability to provide accurate, real-time valuations, combined with its user-friendly interface and detailed market insights, positions it as a valuable tool for real estate professionals, investors, and regulators alike. The DSS addresses several key challenges in property valuation, including fluctuating market conditions and the complexities of data interpretation. Its scalable design and the continuous learning capabilities of its AI models ensure that the system remains relevant and accurate as market dynamics change.

Looking ahead, we aim to expand the system's capabilities by incorporating more advanced AI models and integrating additional data sources. These improvements will not only enhance the performance of the DSS but also contribute to greater transparency and efficiency in real estate markets around the world. Moreover, the ongoing integration of machine learning algorithms such as neural networks, random forests, and deep learning techniques will allow the DSS to handle even more complex data sets and produce increasingly precise predictions. This evolution will significantly enhance the accuracy of property valuations and provide valuable insights into market trends and potential investment opportunities.

While the current version of the DSS has proven to be highly effective, there remain areas for further refinement. The high initial development cost and the need for substantial computational power for larger datasets present challenges to widespread adoption, especially for smaller firms and independent professionals. Overcoming these obstacles will require ongoing research into cost-effective solutions and the optimization of the underlying algorithms to reduce computational demands. Future advancements could also involve the incorporation of additional external factors, such as economic indicators, regulatory changes, and demographic shifts, which would enhance the DSS's ability to provide holistic and dynamic property valuations.

In conclusion, the AI-powered DSS represents a groundbreaking innovation in property valuation, offering unprecedented accuracy, scalability, and real-time insights. As technology continues to evolve, the potential for such systems to reshape the real estate industry is vast. The continued development of AI models, along with the integration of diverse d ata sources, will further enhance the DSS's ability to meet the demands of a rapidly changing market, providing a more efficient and transparent valorization process that benefits all stakeholders involved in the real estate sector.

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