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SOUTH EAST EUROPEAN JOURNAL OF SUSTAINABLE DEVELOPMENT

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Editorial Foreword

Prof. Dr. Sani Demiri

Editor in Chief

ACKNOWLEDGEMENT

Dear Readers, Authors and Collaborators,

Mother Teresa University in Skopje is pleased to present **Volume 2 (2026)** of the *South East European Journal of Sustainable Development (SEEJSD)*. This edition builds on the momentum generated by the **TSD 2025** conference and features a selection of rigorously peer-reviewed papers addressing key sustainable development challenges in the Western Balkans and beyond.

The volume showcases advances in **green and renewable technologies**, **policy frameworks supporting European integration**, and **AI-driven solutions for environmental sustainability, and sustainability of international migration and peace and security**. Its interdisciplinary scope spans research on renewable energy systems, urban resilience and smart city strategies, cybersecurity as a pillar of digital sustainability, and the socio-economic dimensions of climate adaptation.

Under the leadership of **Editor-in-Chief Sani Demiri, PhD**, the contributions in this issue are closely aligned with the **United Nations Sustainable Development Goals (SDGs)** and propose practical, evidence-based pathways for regional development and long-term resilience.

We extend our sincere appreciation to the authors, reviewers, and institutional partners whose commitment and expertise made this volume possible. We invite the academic and professional community to engage with these works, contribute new research, and collaborate with us in future editions to further amplify their impact.

Sincerely,
Prof. Dr. Sani Demiri, PhD
Editor in Chief

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AUTOMATION AND CONTROL OF INDUSTRIAL WASTEWATER TREATMENT PROCESSES

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Abstract. This paper discusses our research and development of an automated system for industrial water purification. The water treatment system is implemented in the industrial zone of Bunardjik. Rotating biological contactors (RBCs) were applied as a vital technology in the field of wastewater treatment. Their unique design enhances the natural processes of microbial biofilms to efficiently degrade organic pollutants and reduce nutrient levels in wastewater. We utilized monitoring and maintenance practices, emphasizing the need for proper supervision to ensure optimal operation of these systems.

Our setup uses a Biorotor Tehnix 200 system alongside Siemens LOGO RC!24 software to manage water purification tasks. Initially, we applied a sensor to track how acidic the waste stream is, feeding data straight into the LOGO RC!24. Inside the main holding tank, we embedded two pumps for waste processing: one running, and the second as backup. From the results obtained, we can say that the Biorotor Tehnix 200 stands out as an innovative solution in the field of wastewater treatment. Its strengths, such as high efficiency, compact design, and cost-effectiveness, make it an attractive option for many facilities. However, potential weaknesses should be carefully considered, including high initial capital investment and maintenance requirements.

Keywords: Water pollution, Aerobic wastewater treatment, Process automation, PLC control, Biorotor Tehnix 200, Siemens LOGO 24! RC.

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1. INTRODUCTION

Wastewater treatment, which involves cleaning water contaminated by human activities before it is discharged back into the environment, is a vital element of modern environmental management. By removing pollutants and hazardous substances, wastewater treatment helps protect water bodies and ensures their safe and sustainable use for purposes such as drinking, recreation, agriculture, and industrial operations. It includes a variety of processes aimed at removing physical, chemical, and biological contaminants from water generated by households, industries, and agricultural activities.

Recent developments in wastewater treatment emphasize the automation and control of treatment processes for contaminated water. When wastewater is left untreated, it can lead to serious health and environmental problems, including the spread of waterborne diseases, damage to aquatic ecosystems, and contamination of drinking water sources. Effective wastewater treatment systems significantly reduce these risks and support the sustainable management of water resources.

Numerous studies have been conducted in the field of wastewater treatment. For example, Cakmakcı et al. [1] developed an automated SCADA system for the monitoring and control of the Kayseri wastewater treatment plant. Their system monitors key parameters like flow rate, COD, pH, and suspended solids, using a control mechanism to handle pollutants. Deng, L. et al. [3] combined traditional attached growth processes with membrane bioreactors (MBRs) to overcome limitations like membrane fouling and limited pollutant removal.

Rout. P.R. et al. [11] developed nutrient removal from domestic wastewater by utilizing different conventional, as well as advanced treatment technologies practiced for the removal of nutrients from domestic wastewater. Ning S. and Hong S. [12] developed programmable logic controller-based automatic control for municipal wastewater treatment plant optimization. They utilized an incremental proportion and integration (IPI) control algorithm-based PLC used to adjust the aeration tank's dissolved oxygen content automatically in the wastewater treatment process.

In this paper, we describe our wastewater purification system by utilizing Biorotor Tehnix 200 and LOGO!Soft software by Siemens. In section 2, we describe the processes for water purification, in section 3, rotating biological contractors are described, section 4 presents the Biorotor Tehnix system, and sections 5 and 6 present our practical setup and implementation, utilizing the LOGO!Soft by Siemens.

2. PROCESSES FOR WATER PURIFICATION

Wastewater treatment processes provide clean and safe water for reuse or discharge into nature without harmful effects on the ecosystem. These processes can be classified into three basic categories: physical, chemical, and biological processes. Each of these processes plays an important role in removing contaminants from water and improving its quality (e.g., pH value).

2.1. Physical Processes

Physical treatment processes involve mechanical methods for removing solid particles and suspended solids from wastewater. These processes most commonly use the following methods:

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(a) *Sedimentation* - where the wastewater is allowed to settle in a tank, allowing substances that are heavier than water to sink to the bottom of the tank by gravity and form a sediment. This sediment can then be removed through an opening in the bottom of the tank, thereby purifying the water of solid settleable substances.
(b) *Filtration* is a method that uses various types of filtration techniques to remove particles and impurities from water. Filtration can be mechanical, such as using sand or activated carbon, or membrane, which uses semi-permeable membranes.
(c) *Aeration* is a process that involves introducing air into wastewater to remove grease or to increase the concentration of dissolved oxygen and enable the growth of biomass needed to reduce organic pollutants.

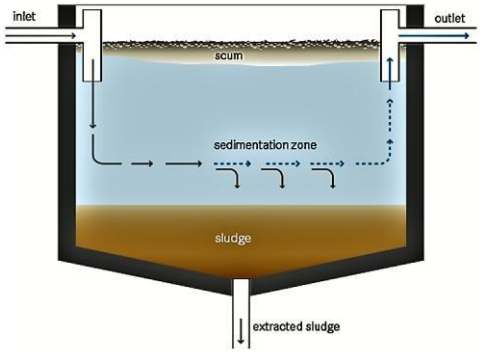

Fig. 1. a) Sedimentation process. b) Plant for membrane water filtration.

2.2. Chemical Processes

Chemical treatment processes utilize various chemical compounds to neutralize or remove contaminants. These processes use the following methods to achieve chemical reactions:

(a) *Neutralization* is a method used to correct the pH of water, especially when wastewater contains acids or bases. Chemicals such as sodium hydroxide or weak acids can be added to achieve a neutral pH.
(b) *Oxidation* is a process that involves the use of oxidants, such as chlorine or ozone, to destroy organic and pathogenic contaminants. This is especially important in the treatment of industrial wastewater, to prevent it from being harmful to the environment.
(c) *Coagulation* and *flocculation* are processes that involve the addition of chemical compounds that help group small particles into larger agglomerates, which can then be removed through sedimentation or filtration.

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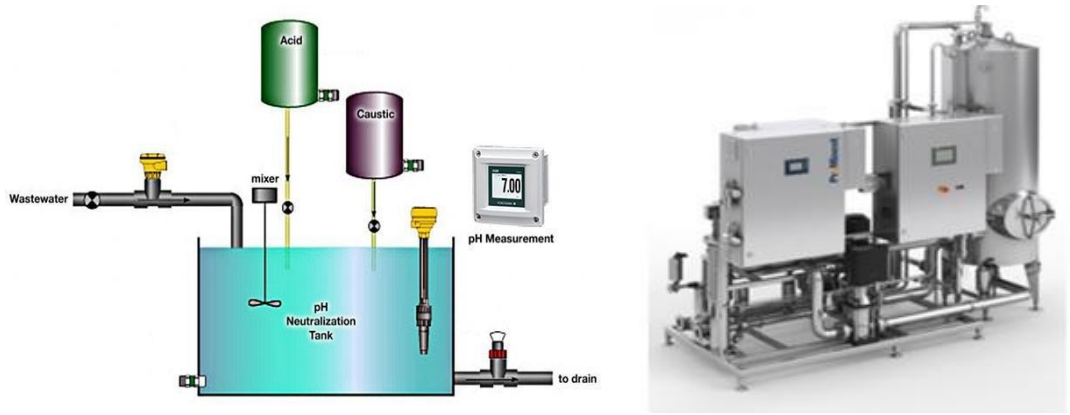

Fig. 2. a) System for neutralization of wastewater. b) System for ozone generation (20-40g).

2.3. Biological Processes

Biological wastewater treatment processes use microorganisms to break down organic materials. These processes can be:

(a) *Aerobic biological treatment*, which involves the use of aerobic bacteria that feed on organic pollutants, converting them into water, carbon dioxide, and new biomass. These systems are known as convection wastewater treatment systems and can operate with suspended activated sludge or as fixed-bed systems, where a mechanical support is used to fix the biomass.

(b) Anaerobic biological treatment is carried out in oxygen-free conditions, allowing anaerobic microorganisms to decompose organic matter and generate methane as a by-product. This approach is particularly effective for treating wastewater containing high levels of organic contaminants that require significant organic material removal.

(c) Phytoremediation is an eco-friendly method of cleaning contaminated water through the use of plants. Plants use their root systems to absorb, process, and degrade contaminants. These technologies are integrated into various wastewater treatment systems that are customized to diverse types of wastewater, providing effective and sustainable solutions for water resource management.

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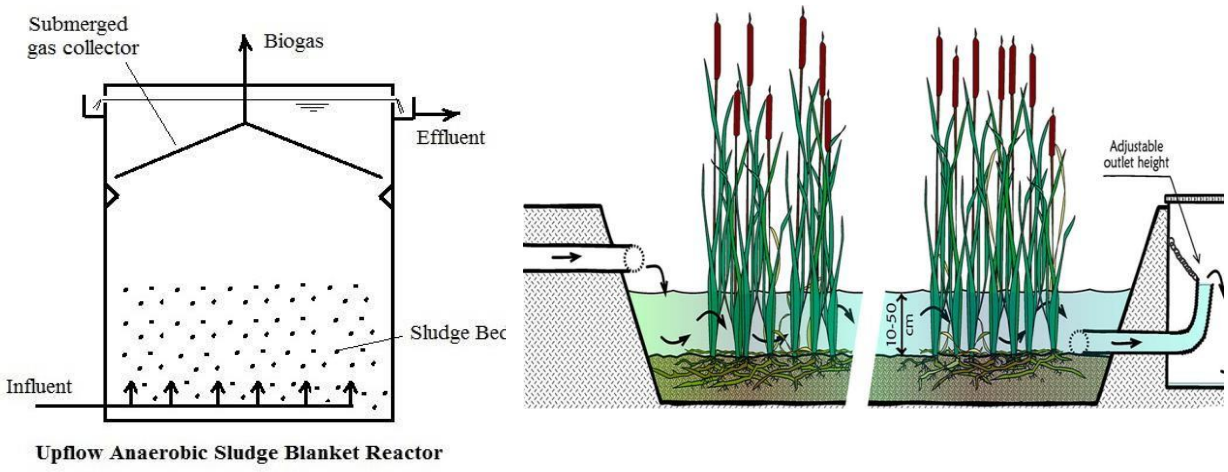

Fig. 3. a) Anaerobic biological processing. b) The method for phytoremediation.

3. ROTATING BIOLOGICAL CONTACTORS IN WASTEWATER TREATMENT

Rotating Biological Contactors (RBCs) are a form of biological wastewater treatment system that use a network of closely spaced, revolving discs or media that are partially immersed in wastewater. These discs are made of ingredients that promote the growth of microorganisms and the formation of a biofilm, which is required for the treatment procedure. As the discs revolve, the attached biomass is alternatively brought into touch with the wastewater and then exposed to air, creating suitable circumstances for microorganisms to aerobically degrade organic matter.

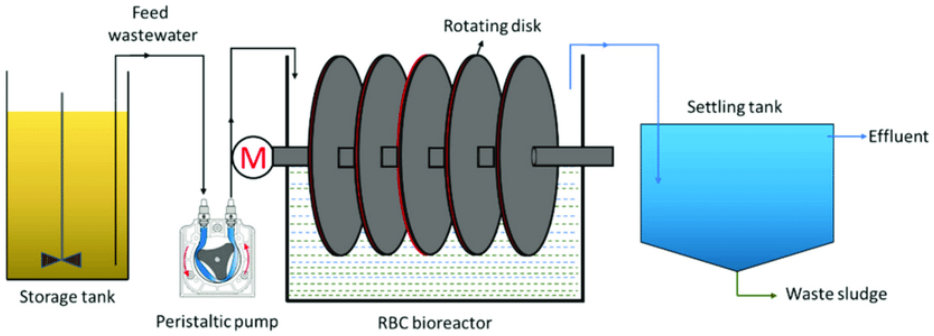

Fig. 4. Working diagram of a rotating biological contractor.

The RBC concept was first introduced in the 1960s, when engineers wanted to improve the effectiveness of biological treatment procedures while saving space and area. Trickling filters and other existing technologies affected early designs. The use of RBCs provided improved microbial control and increased system design flexibility. Today, RBCs are generally recognized for their capacity to treat a wide range of wastewater, including streams with high organic loads and changing temperatures.

A critical component of RBC operation is the creation of a microbial biofilm on the surface of the revolving discs. This biofilm is a complex population of microorganisms, including bacteria, protozoa, and fungi, that work together to break down organic materials and other contaminants

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in the wastewater. As microorganisms proliferate and build a balanced community, the biofilm thickens and becomes more stable over time.

4. BIOROTOR TEHNIX FOR WATER TREATMENT

The Biorotor Tehnix 200 is an innovative aerobic biological system designed for wastewater treatment. It uses fixed-film technology, which allows microorganisms to grow on a rotating substrate that is partially submerged in wastewater. This system was implemented in Bunardjik to aid in the degradation of organic contaminants, making it a viable option for treating a variety of wastes.

The Biorotor Tehnix 200 has an average hydraulic retention time of about 24 hours to enable adequate biological treatment. The system consists of a reception chamber with two pumps, one working and one backup, as well as a protective mesh that keeps solid waste from entering and causing damage to the system. In addition, the system includes the following components:

- Hydromechanical unit with specified dimensions for various chambers (reception, aeration, biological treatment, and secondary sedimentation) together with pumps and aerators used in the system.
- Operational dashboard showing how the wastewater enters the reception chamber, where solid waste is filtered. The remaining wastewater undergoes biological treatment using specially cultivated bacteria.
- Mechanisms for recirculating the treated water in the treatment process to improve operational efficiency.
- Control panel to control the operation of the electrical equipment. The pumps operate in pairs to provide redundancy, and the system is designed to respond to fluctuations in water inflow.

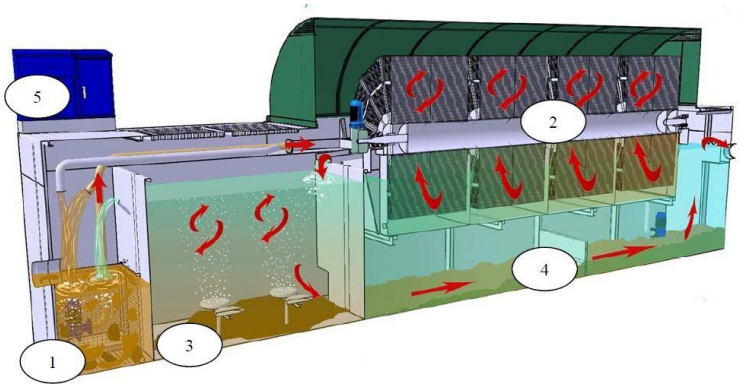

Fig. 5. Structural diagram of Biorotor Tehnix 200

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Fig. 6. Practical construction of Biorotor Tehnix 200

5. HARDWARE AND SOFTWARE SETUP

The Siemens LOGO series represents an important development in programmable logic controllers (PLCs), particularly for small-scale automation applications. Its modular design allows a wide range of input and output modules to be easily integrated, enhancing both functionality and flexibility to meet diverse automation requirements.

For the purpose of our Biorotor Tehnix control – we have utilized Siemens' Micro PLC, which is fully programmable by LOGO!Soft package.

LOGO!Soft comfort is GUI-based toolbox, allowing users to utilize its basic elements such as inputs, outputs, timers and logic functions. The platform enables simple programming of digital and analog inputs, allowing users to efficiently read sensors and control actuators.

Fig. 7. Micro PLC by Siemens, programible with LOGO!Soft.

In the first part of our water treatment process, we've installed a probe to measure the pH of the incoming wastewater, which provides information to LogoRC!24. At the same time, two pumps are installed in the primary pool, which is an integral part of the wastewater treatment unit, one is working and the other is standby. The signals from the thermal protections of the two pumps are connected to the Input 1 (I1) and Input 2 (I2) sections of LogoRC!24. A 24V transformer is used to power the LogoRC!24. Consequently, Input 3 (I3) is the input for the thermal protection of the

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biorotor and is also the main alarm. In Figure 20, the biorotor is marked with the number 2, while the pumps for feeding the system are placed in pool number 1 (I1 and I2).

6. IMPLEMENTATION AND RESULTS

The main technological units of the Biorotor Tehnix (see Fig. 5) are:

1. Reception chamber with a grid, a filling station and recirculation,
2. Biorotor constructed of polypropylene elements,
3. Aeration basin with diffusers,
4. Secondary sedimentation tank for settling suspended solids from the aeration basin,
5. Control panel in which the automation and LogoRC!24 are installed.

Q1-Feeding pump for the system installed in pool number 1 in Fig. 5,
Q2-Backup feeding pump for the system installed in pool number 1,
Q3-Biorotor marked with number 2,
Q4-Activated sludge recirculation pump installed in pool number 4,
Q5-Low pressure blower for aeration of pool number 3,
Q6-Dosing pump for pH correction (acidic environment),
Q7-Dosing pump for pH correction (basic environment),
Q8- Heaters for maintaining a minimum temperature of 10˚C.

The float, which is placed in base number 4 and serves as protection for the recirculation pump, is connected to Input number 10. This pump operates in given time periods (5 min on/ 55 min off). The operating mode of the pump can be changed via PLC. For programming the pump, a block with an asynchronous pulse generator is used, which is marked with B005 in the program. In base number 3 in Figure 20, two disk-shaped diffusers are placed, which are used for aeration of activated sludge. In this section, air is obtained using a low-pressure blower that operates in a cyclical time period of 30 min. (30 min on/ 30 min off). The thermal protection of the blower is connected to Input 5 (I5).

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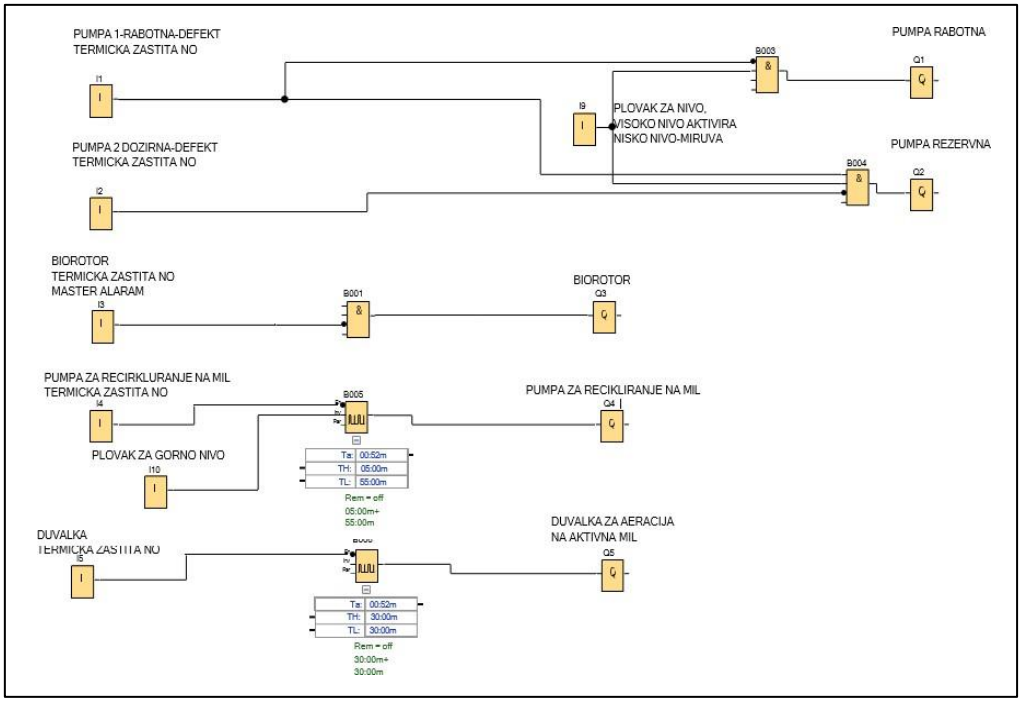

Fig. 8. Control diagram for water purification developed in LOGO!Soft and connected with Biorotor T.

The signal from the pH Sensor is amplified (B013-analog amplifier), compared, and activated using the Biorotor blocks B011 and B012 (Analog Threshold trigger). Depending on the pH value, the outputs Q6 or Q7 are activated, which activate the caustic soda or acid dosing pumps, thus purifying the water. This system is installed in small pH control stations to supply precise quantities of cleaning chemicals (hydrochloric acid, for cleaning floors, or caustic soda for unclogging sewers from fats and oils).

7. CONCLUSIONS

Using the above setup of Biorotor Tehnix 200 and the LOGO!Soft by Siemens, in Bunardjik zone we have achieved a water purification factor of 90%, and made the water pH within normal limits (6.5-8.5).

The proposed system offers several key advantages. First, it provides high treatment efficiency, as RBC technology allows microorganisms sufficient contact time with the wastewater, resulting in effective removal of contaminants. In addition, the compact design of the Biorotor significantly reduces the space required compared to conventional treatment systems, which is particularly beneficial in urban areas where available land is limited. The system is also cost-efficient over the long term, as its energy-efficient operation helps lower operating expenses while maintaining high performance. Furthermore, the Biorotor Tehnix 200 is flexible in application and can be adapted to treat different types of wastewater, making it a versatile solution for a range of treatment scenarios.

However, several limitations should also be taken into account and will be addressed in future work. Although the Biorotor Tehnix 200 is economical in the long run, the initial capital

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investment required for installation can be relatively high. The system also requires regular maintenance to ensure reliable and optimal operation, which means that facilities must allocate sufficient resources for upkeep. Finally, while suitable for many applications, the scalability of the Biorotor may be limited in situations with very high treatment demand.

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THE IMPACT OF ARTIFICIAL INTELLIGENCE ON ENHANCING THE LEARNING PROCESS: A LITERATURE REVIEW

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Abstract

Artificial Intelligence (AI) is transforming the field of education by creating new and powerful ways to support teaching and learning. Through tools such as personalized learning systems, adaptive assessments, and intelligent feedback, AI allows students to learn at their own pace and receive support tailored to their needs. This literature review examines the most recent studies on how artificial intelligence (AI) is being used in schools and its impact on learning outcomes and to understand how AI is influencing the learning process. The review identifies essential themes through the analysis of contemporary scholarly publications, including personalized learning systems, intelligent tutoring systems, automated assessment tools, and adaptive learning platforms. The findings suggest that artificial intelligence demonstrates very high potential in enhancing student engagement, offering personalized training, and improving learning efficiency and speed. This review combines real-world data and theory to help educators and researchers clearly understand how AI fits into modern education.

Overall, this paper not only highlights the positive impact of AI on education but also offers recommendations to help schools, teachers, and policymakers integrate AI more effectively. It also outlines key areas where further research is needed to ensure that AI supports all learners in a fair, responsible, and useful way.

Keywords: *Artificial Intelligence, Educational Technology, Personalized Learning, Learning Outcomes, Adaptive Learning, Intelligent Tutoring Systems (ITS), Automated Assessment*

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1. Introduction

Artificial intelligence (AI) refers to the ability of a computer or machine to perform tasks that would normally require human intelligence, such as learning, problem-solving, decision-making, and more. There are several different approaches to building AI systems, including machine learning, where a system is trained on a dataset and can improve its performance over time, and rule-based systems, where the system follows a set of predetermined rules to make decisions.

AI can be applied to a wide range of areas, including natural language processing, image and video recognition and robotics. The goal of AI research is to create systems that can perform tasks at least as well as, or ideally better than, humans. AI has the potential to revolutionize many industries and transform the way we live and work, but it also raises important ethical and social questions.

Artificial intelligence (AI) is technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy.

Artificial Intelligence (AI) is becoming an important part of modern education. It offers new ways to support teaching and learning by making learning more personalized, helping teachers with routine tasks, and improving how students receive feedback. As schools and universities face challenges such as different learning needs, limited resources, and the demand for digital skills, AI tools provide helpful solutions.

These technologies can increase student engagement and help improve academic results. There are also challenges in using AI in education. Concerns about data privacy, fairness, and equal access to technology must be considered. The success of AI tools also depends on how well they fit the teaching goals and the needs of learners.

The term AI – "Artificial Intelligence" was first introduced on July 13, 1956, following John McCarthy's 1955 proposal submitted to the Rockefeller Foundation. Technology and technical systems are undergoing rapid and dynamic development, which significantly influences the advancement of AI. Stephen Hawking described the development of Artificial Intelligence as a threat to humanity, warning that it could potentially contribute to the extinction of the human race.

"The development of full artificial intelligence could spell the end of the human race. It would take off on its own and redesign itself at an ever-increasing rate. Humans, who are limited by slow biological evolution, couldn't compete and would be superseded." [1]

Artificial Intelligence is a branch of computer science with an interdisciplinary nature. We are witnesses to a time in which AI is becoming one of the most influential technologies, transforming the way we work, learn, and develop. AI has also had a powerful impact on the education process, as it is identified as a highly capable tool that can enhance learning by enabling personalized instruction. It can automate routine tasks and assist teachers in making more data-driven decisions. As schools face new learning demands such as digitization and the need for accessible educational resources, AI offers innovative ways to support both students and teachers.

Rapid developments in learning analytics, machine learning, intelligent tutoring systems, and natural language processing have enabled the creation of diverse AI tools. This has made

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AI increasingly accessible to students and educators, directly facilitating their work. Learning materials are available instantly, meaning that useful educational content can be generated on demand. Teachers are relieved from administrative burdens and can focus more on high-quality instruction and meaningful interaction with students. AI is increasingly viewed as a strategic instrument for improving the learning process by enabling personalized learning, automating routine tasks, and supporting data-driven decision-making. It provides innovative solutions aimed at improving both the quality and efficiency of education.

However, the use of AI in education is becoming more complex. Important issues such as data privacy, algorithmic bias, fairness, and unequal access to technology must be addressed. The effectiveness of AI tools also depends on how well they are designed and how effectively they are integrated into teaching and learning practices.

This literature review gathers research on how AI can enhance the learning process. It examines key concepts, practical applications, advantages, and challenges of AI in education. Critical issues such as personal data protection, algorithmic risks, ethics of data use, and technological inequality require special attention. Furthermore, the effectiveness of AI tools depends on their design quality, the institutional context in which they are implemented, and the ability of teachers and students to use them wisely and critically.

This research paper aims to analyze, in a structured manner, the role of AI in improving the learning process. It explores core concepts, practical applications, advantages, and challenges associated with integrating AI into education, drawing on contemporary studies and diverse expert perspectives. The primary goal is to provide a clear theoretical and practical framework for researchers, educators, and developers seeking to harness the potential of AI to enhance learning quality and guide education toward more advanced and innovative models.

2. Literature review

The study [1] examines the technological, pedagogical, and social developments that have shaped the field of education over the past 50 years. They analyzed trends in educational theory and educational system design. AI in education has evolved from rule-based expert systems to modern adaptive, data-driven, and intelligent teaching technologies.

They found that early systems focused on automation and logic, while current technologies emphasize personalization, analytics, and human-AI collaboration.

One of the main conclusions is that AI should be used as an aid that supports the learning process, not as a replacement.

The paper [2] aims to assess the impact of artificial intelligence (AI) on education, focusing on how AI is applied and what effects it has in learning too. A qualitative literature review method was used: they survey existing studies and systems to draw conclusions about adoption, applications, and outcomes.

“AI” is defined as the field that produces systems (computers, machines) with “human-like

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intelligence": cognitive abilities, learning, adaptability, decision-making.

The authors conclude that AI has significant transformative potential for education, offering improvements in administration, instruction, and learning that can enhance efficiency, personalization, and overall quality. AI can provide timely, consistent feedback; support interactive or intelligent tutoring; enable more responsive/adaptive instruction. AI offers ability to tailor curriculum and content to individual learners' needs helps increase engagement, knowledge retention, and overall learner satisfaction.

While symbolic AI and rule-based systems dominated the early landscape, 2005–2020 marked a shift toward data-driven models powered by machine learning. These systems no longer relied solely on expert-designed rules; instead, they learned patterns from data to personalize instruction, predict performance, or recommend resources. Highlighted this shift, tracing a transition from early knowledge-based tutors to modern learning analytics dashboards, adaptive platforms, and AI-driven assessment solutions. Machine learning enabled systems such as adaptive learning platforms that dynamically adjust difficulty based on learner performance demonstrated the evolution of AutoTutor into a family of conversational tutoring agents supported by NLP. These systems use statistical models to analyze student responses, generate feedback, and simulate natural dialogue.

[4] and [5] observed that the COVID-19 pandemic dramatically accelerated adoption of AI tools, with educational institutions integrating adaptive platforms, AI chatbots, and automated assessment tools into remote teaching ecosystems. This period highlighted AI's potential to support continuity of learning, reduce teacher workload, and provide individualized instruction during widespread disruption.

Steenbergen-Hu & Cooper [12] concluded that Intelligent Tutoring Systems produce strong, statistically significant improvements in college students' academic performance. The researchers found that ITS interventions resulted in better test scores, higher conceptual understanding, and more efficient study time. The study also indicated that ITS can be as effective—or sometimes more effective— than one-on-one human tutoring. The authors noted that ITS works best when integrated into regular coursework rather than being used as a standalone tool.

Adaptive learning systems use predictive modeling and analytics to adjust learning pathways. Wang and Zheng [2] note that adaptive platforms: automatically adjust content

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sequencing and improve efficiency by reducing redundant learning.
These systems often integrate with learning management systems (LMS), providing seamless data flow to support teacher decision-making emphasized that sustainability in education is not only about environmental factors, but also scalability, accessibility, long-term availability, and pedagogical durability. The review highlights that AI-driven ITS are being increasingly used in regions with limited teachers or inconsistent instructional quality, making them valuable infrastructure for equitable learning. Students benefit from feedback tailored to their needs, pacing that matches their mastery levels, and automated assessment that reduces teacher workload.

[18] examines how an ITS performs for students with varying levels of programming background. Results show that all learners benefited significantly from the ITS, but the nature of the benefits differed. Novices gained more from corrective feedback, step-by-step hints, and structured practice tasks. The study concludes that ITS can accommodate heterogeneous classrooms effectively, but that user experience design must be sensitive to prior knowledge. It reinforces the idea that "one-size-fits-all" ITS systems underperform, and that future systems should employ fine-grained learner modeling to adjust difficulty, explanation length, and feedback style based on the student's starting point.

Adaptive learning [16] provides students with highly personalized learning experiences. Using AI and machine learning, these systems examine each learner's strengths, weaknesses, and preferred learning styles to adjust the content, pace, and instructional methods accordingly. This individualized approach increases engagement and motivation, supports deeper knowledge retention, and ultimately enhances academic achievement.
In addition, adaptive learning platforms deliver real-time feedback and track learner progress, allowing educators to quickly identify areas where students may be struggling and offer timely support. By processing large amounts of data, AI and ML can recognize learning patterns and generate meaningful insights for both learners and instructors. This data- driven approach not only supports targeted interventions but also contributes to the ongoing enhancement of the overall e-learning environment.
[14] demonstrates that AI-driven adaptive learning systems are effectively transforming higher education through enhanced personalization and improved learning outcomes. The analysis reveals consistent positive impacts on student engagement and academic performance, with studies reporting improvements ranging from 15% to 25% in learning outcomes. These systems have proven particularly effective in providing real-time feedback, adapting to individual learning patterns, and creating personalized learning pathways that address diverse student needs.

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[15] shows that AI-powered personalized learning systems significantly enhance educational outcomes by enabling real-time adaptation, boosting student engagement, and providing cognitive support tailored to each learner's needs. The research also underscores the importance of ethical safeguards to ensure these systems foster equity and inclusion.

Across all cases, the key finding was that personalized learning algorithms could adjust content dynamically based on student performance. By analyzing data in real time, these systems were able to modify learning paths, offering challenges that matched each student's skill level, preventing boredom or frustration. Unlike traditional models with standardized content and assessments, the APT theory's adaptive assessments deliver immediate feedback, allowing students to make continuous progress.

3 Research Methods

This study uses a **Systematic Literature Review (SLR)** to examine the impact of Artificial Intelligence (AI) on enhancing the learning process.

This study also uses a descriptive research method to analyze the use of AI tools in teaching in the fields of computer science, focusing on the most accessible Artificial Intelligence (AI) tools.

The research was conducted through a mixture of literature analysis and practical case studies, as well as the collection and review of data from several educational institutions in our country.

3.1 Participant group

The research includes students from mathematics–informatics high schools and undergraduate students from the Faculty of Informatics, who have access to AI tools: ChatGpt, Claude, Gemini. Data were collected from students who have used AI for educational projects and teaching in the fields of computer science.

3.2 Data collection method

Surveys and questionnaires: Data were collected through a survey containing questionnaire.

The questionnaire included closed-ended Likert-scale items measuring students' perceptions of AI-supported learning across several dimensions, including feedback quality, cognitive support, learning efficiency, ease of use, motivation, engagement, self-regulation, and perceived academic performance. Also this allow students to evaluate their experience with the use of AI tools in the learning process.

The questions in the questionnaire are:

1. **AI tools help me learn better**
2. **AI makes my learning easier.**
3. **AI gives me helpful feedback.**
4. **AI helps me understand difficult topics.**
5. **AI saves me time when studying.**
6. **AI makes learning more fun.**
7. **AI helps me improve my grades.**

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8. I learn faster when I use AI tools.

This questionare also included closed-ended Likert-scale items to measure Perception of AI vs. human teacher effectiveness and Credibility and trust in AI for learning. For this purpose, we included the following questions:

1. AI gives me inaccurate answers or misleading information
2. AI makes me passive and reduces my creativity
3. AI tracks my activities without me knowing.
4. AI sometimes makes me feel confused
5. AI cannot provide me with the kind of learning I receive from a teacher

Response scale used:

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

Interviews with teachers and instructors: In addition to the surveys, interviews were also conducted with several teachers and instructors who are engaged in teaching computer science subjects using AI tools. These interviews enabled the collection of information regarding the teaching methodology, the use of AI tools and the benefits they have observed during the development of teaching.

The main hypotheses addressed in this research study are as follows:

H1: AI-based learning tools positively affect students' academic performance and enhances student engagement and motivation in the learning process.

H2: The use of AI-based learning tools has no significant negative effect on students' creativity, active engagement, or cognitive clarity in educational settings.

The results obtained from the questionnaire will be analyzed and discussed for each individual question.

4 Analysis of the Findings Derived from the Questionnaire

4.1 Perceptions of AI-supported learning across several dimensions, including feedback quality, cognitive support, learning efficiency, ease of use, motivation, engagement, self-regulation, and perceived academic performance.

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1. AI tools help me learn better

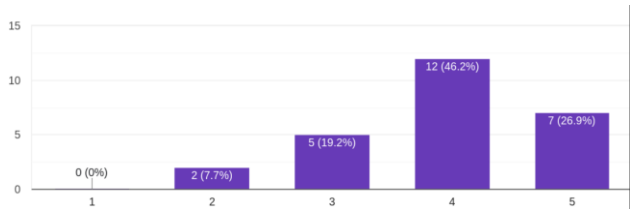

Figure 1: AI tools healp me learn better

The results indicate a strongly positive perception of AI tools in supporting learning. Out of 26 respondents, the majority selected the higher end of the Likert scale.
73% of respondents agree or strongly agree that AI tools help them learn better, showing a clear positive trend. A smaller portion of participants expressed a neutral or slightly negative view.

2. AI makes my learning easier.

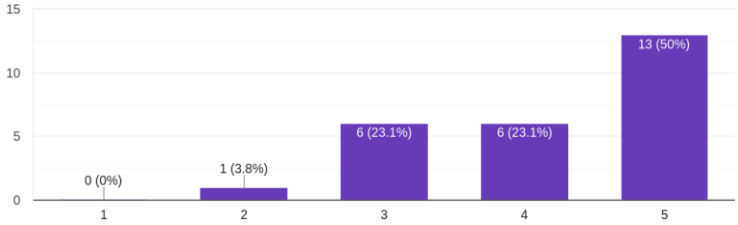

Figure 2: AI makes my learning easier

The findings show a very strong positive perception of Artificial Intelligence in simplifying the learning process. 73% of respondents agree or strongly agree that AI makes their learning easier, indicating on the usefulness of AI tools in reducing learning difficulty.

3. AI gives me helpful feedback.

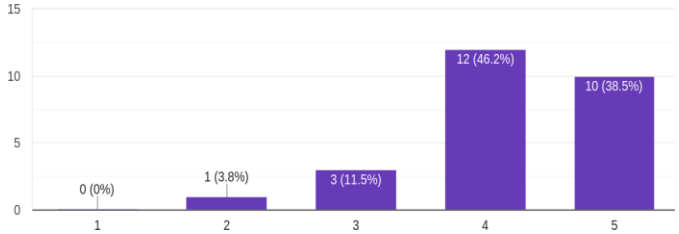

Figure 3: AI gives me helpful feedback.

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The results demonstrate a strong positive perception of AI's ability to provide helpful feedback during the learning process.
85% of respondents agree or strongly agree that AI provides helpful feedback, indicating that feedback is one of the most valued benefits of AI-supported learning. A small minority expressed uncertainty or slight disagreement

4. AI helps me understand difficult topics.

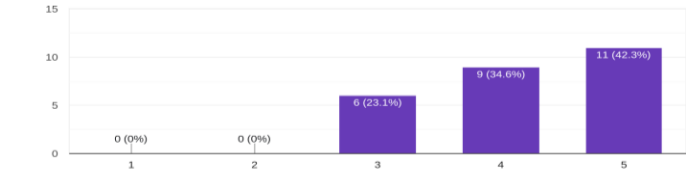

Figure 4: AI helps me understand difficult topics 4

The results show a strongly positive trend. A total 76.9% of students expressed a positive perception. 23.1% selected the neutral option. Importantly, no respondents disagreed or strongly disagreed with the statement.
These findings indicate that students widely perceive AI tools as effective in supporting the comprehension of complex or challenging learning material. The absence of negative responses suggests a high level of acceptance and trust in AI as an educational aid. AI tools appear to play a significant role in simplifying difficult concepts, providing explanations, and enhancing conceptual understanding.

5. AI saves me time when studying.

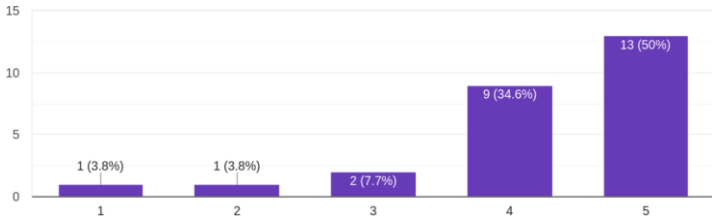

Figure 1: AI saves me time when studying

The majority of participants agreed with the statement, meaning that **84.6%** of respondents believe that AI helps them save time while studying. A smaller proportion (**7.7%**) selected the neutral option.
Only **3.8%** disagreed and **3.8%** strongly disagreed, indicating minimal negative perception. These findings suggest that students widely perceive AI tools as efficient and time-saving learning aids. AI appears to help students complete tasks faster, find information more quickly, and streamline their study process.

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6. **AI makes learning more fun.**

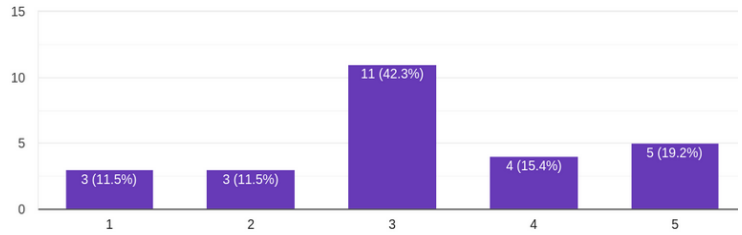

Figure 6: AI makes learning more fun

The most common response was "3" (Neutral), selected by 42.3% of participants, indicating that for nearly half the class, AI does not significantly alter the enjoyment of learning—it is neither fun nor boring, just a tool. At the same time, 23% of respondents (combining 1 and 2) actively disagreed that AI makes learning fun, with 11.5% selecting "Strongly Disagree," a sentiment absent in the efficiency data. Overall, students perceive AI primarily as a functional tool rather than a source of enjoyment. While they recognize its efficiency and productivity benefits, their experiences regarding fun are mixed, suggesting that AI enhances learning outcomes without significantly increasing engagement or enjoyment.

7. **AI helps me improve my grades**

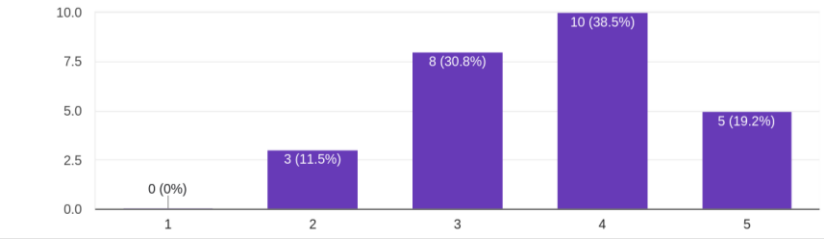

Figure 7: AI helps me improve my grades

Most respondents perceive AI as something that can make learning more fun, but the majority are neutral to moderately positive (rating 3). There is a positive trend, as 42.3% are at least neutral, and 34.6% see AI as a tool that increases learning enjoyment. A smaller portion of respondents do not think AI makes learning more enjoyable 22.9%. The data show that AI can enhance the fun aspect of learning for a significant portion of respondents, though opinions are not unanimous, and some participants remain neutral or skeptical.

The majority of respondents believe AI helps them. If we combine the top two values (4 and 5), **57.7%** of the participants reacted positively to the statement. There is a significant number of "middle of the road" answers. **30.8%** of respondents selected "3," suggesting they may be unsure of AI's impact, or perhaps they use AI but don't attribute their grade improvements directly to it.

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8. **I learn faster when I use AI tools**

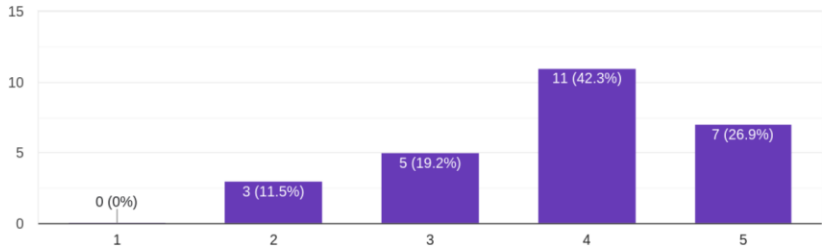

Figure 8: I learn faster when I use AI tools

Nearly **70%** of the participants believe that AI helps them speed up their learning, so they perceive a positive impact. **19.2%** neutral responses suggests that participants are more confident that AI helps them work *faster* than they are that it specifically improves their *grades*. The data strongly indicates that AI tools significantly enhance work speed, while over a quarter report a substantial advantage.

4.2 Perception of AI vs. human teacher effectiveness and Credibility and trust in AI in learning

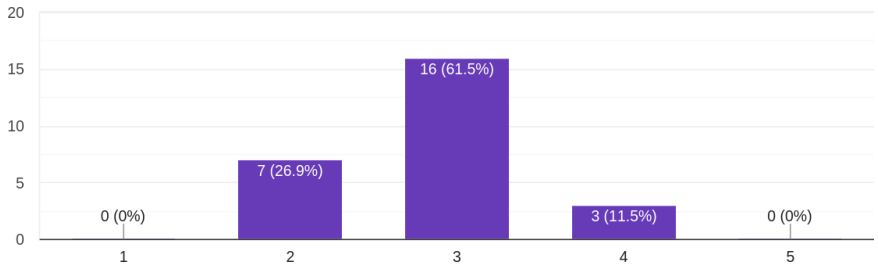

Figure 9: AI gives me inaccurate answers or misleading information

1. **AI gives me inaccurate answers or misleading information**

Most respondents (**61.5%**) selected the neutral option, indicating uncertainty about whether AI provides inaccurate or misleading information. A smaller proportion (**26.9%**) disagreed with the statement, suggesting a general level of trust in AI accuracy, while **11.5%** agreed that AI can produce misleading answers. No participants selected the extreme options. Overall, the results show a predominantly neutral perception, with limited concern about AI reliability.

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2. **AI makes me passive and reduces my creativity**

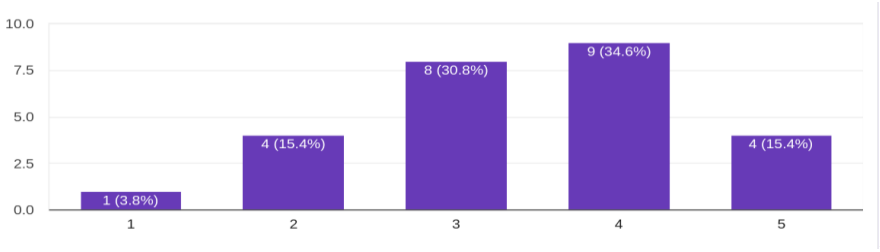

Figure 10: AI makes me passive and reduces my creativity

The results indicate a generally cautious perception of AI's impact on creativity. A total of 50% of respondents agreed or strongly agreed that AI makes them more passive and reduces their creativity, while 30.8% remained neutral. In contrast, only 19.2% disagreed with the statement. This distribution suggests that concerns about reduced creativity and passivity are present among a substantial portion of participants.

3. AI tracks my activities without me knowing.

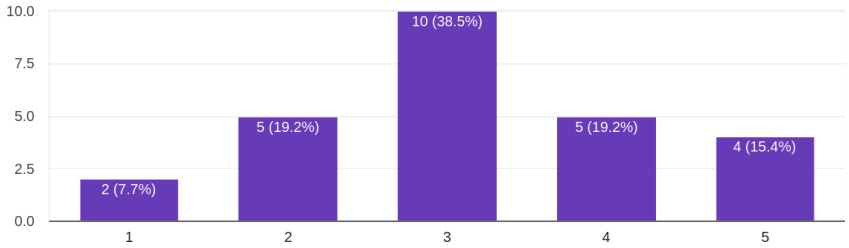

Figure 11: AI tracks my activities without me knowing.

The results show that perceptions of AI tracking activities without users' knowledge are largely neutral. The highest proportion of respondents (38.5%) selected the neutral option (rating 3). Agreement with the statement was reported by 34.6% of participants (ratings 4 and 5), while 26.9% disagreed (ratings 1 and 2). Overall, the findings indicate uncertainty among respondents, with no strong consensus regarding concerns about undisclosed activity tracking by AI.

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4. AI sometimes makes me feel confused

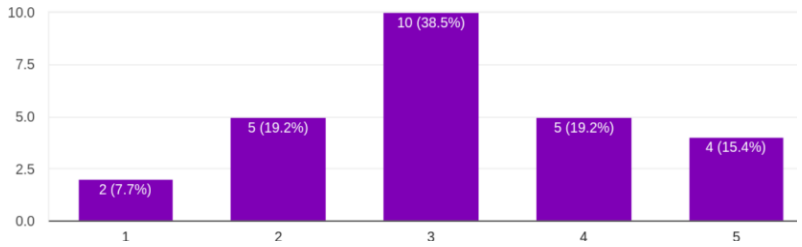

Figure 12: AI sometimes makes me feel confused

The results indicate a moderate tendency toward confusion related to AI use. The most frequent response was option 2 (34.6%), followed by option 3 (30.8%), meaning that 65.4% of respondents selected low-to-moderate levels on the scale. A smaller proportion chose option 4 (19.2%), while very few selected the extremes (options 1 and 5, each 7.7%). Overall, the distribution suggests that confusion is present among many respondents, but it is generally experienced at low to moderate levels rather than as extreme confusion.

5. AI cannot provide me with the kind of learning I receive from a teacher

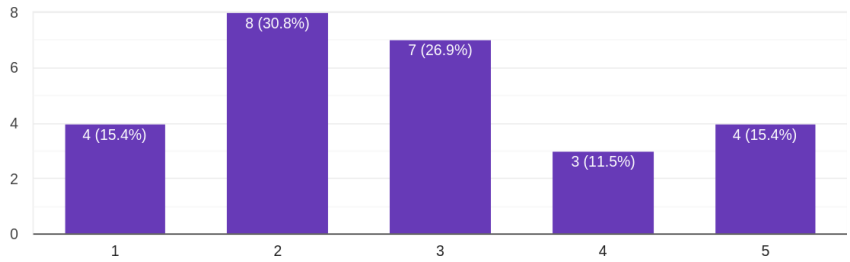

Figure 13: AI cannot provide me with the kind of learning I receive from a teacher

The responses show a notable leaning toward higher agreement with the statement, with most respondents selecting options 2 or 3 (approximately 57.7%).

This pattern indicates that while the concern is present, it is not experienced as severe or overwhelming by most respondents. The minimal selection of extreme responses further suggests a balanced and reflective stance rather than polarized opinions. This suggests that a majority feel they do not receive learning that matches the quality of instruction from a teacher, though there is a meaningful minority who feel less strongly or neutral about this comparison.

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5. Findings and Results

The results across all reviewed studies show that AI has a positive impact on the learning process. The main findings include: Increased student motivation and engagement, improvements in learning performance, personalized and adaptive learning, enhanced feedback through natural language tutoring systems, automation that reduces teacher work

The findings demonstrate that AI-based learning tools play a **positive and supportive role** in improving academic performance while also enhancing student engagement and motivation. Therefore, **H1 is supported**, as students perceive AI as an effective aid that facilitates learning, maintains engagement, and motivates them through personalized assistance and constructive feedback.

The responses show a notable leaning toward higher agreement with the statement, with most respondents selecting options 2 or 3 (approximately 57.7%). This suggests that a majority feel they do not receive learning that matches the quality of instruction from a teacher, though there is a meaningful minority who feel less strongly or neutral about this comparison. To solidify this takeaway, please confirm the exact scale orientation (which end indicates stronger agreement) and consider reporting the mean and dispersion.

H2 is only partially supported.

Students do not strongly perceive AI-based learning tools as problematic in terms of accuracy, which suggests that AI can be considered a generally reliable support for learning and, by extension, academic performance. The absence of strong negative perceptions about misleading information implies that AI is unlikely to hinder learning outcomes significantly.

However, concerns about reduced creativity and increased passivity indicate potential drawbacks for **student engagement and motivation**. A considerable proportion of respondents believe that AI may make them less active or creative in the learning process, which can negatively affect intrinsic motivation and meaningful engagement—key factors for effective learning.

The findings suggest that without proper pedagogical integration, AI tools risk encouraging passive learning behaviors. Therefore, H1 cannot be fully accepted; instead, it highlights the need for structured and guided use of AI to ensure that it actively promotes engagement, motivation, and deeper learning rather than dependency.

6. Conclusions and Recommendations

This literature review shows that Artificial Intelligence can greatly improve the learning process. Many studies found that AI tools help students stay motivated, learn better, and receive more personalized support. Intelligent Tutoring Systems, in particular, are very effective and can sometimes work almost as well as human tutors. Other AI tool like learning analytics, adaptive platforms, and gamified systems also make learning more engaging and help teachers manage lessons more easily.

At the same time, there are important challenges. These include protecting student data, making sure all learners have access to technology, and helping teachers gain the skills needed to use AI properly. It is also important to ensure that AI systems are fair and transparent.

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In general, AI has strong potential to support and improve education, but schools must address these challenges for the technology to be used safely and effectively. More research is needed to understand how patterns AI can be used in the long term and how it can best support both students and teachers.

This study examined students' perceptions of the impact of Artificial Intelligence (AI) tools on the learning process, with a particular focus on learning effectiveness, ease of learning, and the usefulness of feedback provided by AI systems. The findings from the survey of 24 respondents clearly indicate that AI plays a positive and supportive role in enhancing the learning experience.

First, the results show that a strong majority of students believe that AI tools help them learn better. The findings suggest that AI contributes meaningfully to improved understanding and learning outcomes. This supports the view that AI-based tools, such as intelligent tutoring systems and adaptive learning platforms, can effectively complement traditional instructional methods.

AI makes learning easier was also strongly supported. This indicates that AI tools help reduce learning complexity by offering personalized explanations, instant support, and flexible access to learning materials. Such features are particularly beneficial in addressing individual learning needs and promoting independent learning.

The strongest positive response was observed in relation to AI providing helpful feedback. AI offers useful feedback, highlighting one of the most valuable advantages of AI in education. Timely and personalized feedback allows students to identify mistakes, monitor progress, and improve performance more effectively than traditional delayed feedback methods.

The findings suggest that respondents do not perceive AI as highly unreliable, but they also do not express strong confidence in its accuracy. This implies that while AI is generally accepted as a useful tool, users are cautious and may feel the need to verify its outputs rather than rely on it uncritically.

In contrast, perceptions of AI's impact on creativity and passivity are more pronounced. A substantial proportion of respondents agree that AI can make them more passive and reduce their creativity, revealing a meaningful concern about its influence on cognitive engagement and original thinking. Although a notable number of participants remain neutral, the balance of responses leans toward agreement rather than disagreement.

The results indicate that users' primary concern is not the accuracy of AI, but its potential effect on human creativity and active participation. This highlights the importance of promoting AI use as a supportive tool that enhances, rather than replaces, critical thinking and creative effort.

Based on the findings of this study, educational institutions should integrate AI tools, into the curriculum to enhance personalized learning and improve academic performance. Teachers should leverage AI to provide timely and tailored feedback, enabling students to monitor their progress, stay motivated, and address individual learning needs effectively. AI should be used to complement, rather than replace, teacher-led instruction, ensuring that students maintain creativity, critical thinking, and active engagement throughout the learning process.

Schools and universities must implement clear policies on ethical and responsible AI use, including data privacy and transparency, to protect students while using the educational advantages of AI technologies.

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THE IMPACT OF NOTEBOOKLM ON STUDENT COMPREHENSION AND SYNTHESIS IN HIGHER EDUCATION

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ABSTRACT

The rapid adoption of sophisticated Generative AI tools in academia compels a focused inquiry into their measurable pedagogical utility. This study investigates the integration of NotebookLM, an AI-powered research assistant, to determine its effect on undergraduate students' comprehension and synthesis skills in source-based academic inquiry. NotebookLM, which grounds its responses, summaries, and generative outputs entirely in user-uploaded sources (e.g., PDFs, lecture notes), is theorized to mitigate the "hallucination" risk common to general Large Language Models (LLMs). The research problem addresses the persistent gap in the literature regarding the structured pedagogical models for effectively integrating Retrieval-Augmented Generation (RAG) tools into core course objectives. The study's purpose is to quantify performance differences in assignments requiring complex multi-source synthesis, assess student engagement with diverse content formats (e.g., audio/video overviews, mind maps), and evaluate the perceived efficacy of the tool as an aid to higher-order cognitive processing. A mixed-methods approach—combining content analysis of student-generated artifacts against a rubric (comprehension, synthesis, digital literacy), direct observation, and structured feedback—was employed across undergraduate communications courses involving over 102 students during the Fall 2025 semester. Early findings suggest that the structured use of NotebookLM's multimodal and generative tools significantly improved the quality of student submissions, enhanced their ability to connect concepts across disparate documents, and reduced the cognitive load associated with initial literature review, thereby allowing students to allocate more effort to analytical tasks. This research contributes a replicable model for leveraging source-grounded AI tools to facilitate a shift from passive information consumption to active, technology-assisted knowledge construction..

Keywords: AI in education, NotebookLM, comprehension, synthesis, higher education, Generative AI.

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1. Introduction

The contemporary academic landscape is undergoing a seismic shift driven by the proliferation of Large Language Models (LLMs), which challenge traditional paradigms of information retention and synthesis. While the utility of these tools is undeniable, their integration into Higher Education curricula remains contentious, primarily due to the "black box" nature of ungrounded models like ChatGPT, which frequently suffer from hallucinations. We posit that the solution lies not in prohibition, but in the adoption of Retrieval-Augmented Generation (RAG) systems that tether generative capabilities to verified academic sources. This study examines NotebookLM, a Google-developed RAG tool, to assess its specific capacity to enhance student synthesis—a higher-order cognitive skill that requires the amalgamation of disparate information sources into a coherent whole.

The necessity of this research is underscored by the evolving nature of student agency in digital learning environments. As noted by Klemenčič [1], student impact is maximized when learners perceive themselves as active agents in the educational ecosystem; therefore, AI tools must be framed as partners in agency rather than replacements for cognition. Furthermore, the integration of immersive technologies, as explored by Suhag [2], demonstrates that student engagement correlates positively with tools that offer novel, interactive modalities. NotebookLM's specific architecture, which includes "Audio Overviews" and interactive Q&A grounded in specific documents, represents a critical evolution from general LLMs. Recent preliminary work by Liu and Zhao [3] suggests that podcast-style generation from text—a core feature of NotebookLM—can significantly reduce anxiety and improve flow in comprehension tasks. However, a gap remains in rigorously quantifying how these features translate to improved written synthesis in high-stakes assessments.

Socio-economic factors also necessitate efficient learning tools. Remigereau and Schäper [4] [5] highlight the pressures of aid eligibility and application friction, suggesting that students are increasingly time-poor and cognitively burdened. In this context, tools that streamline the low-level mechanical tasks of sorting information may alleviate the cognitive load that exacerbates mental health challenges, a concern raised by Onderi and Oginda [6] regarding the digital well-being of university students. If AI can function as a "cognitive scaffold," it may improve student loyalty and retention by making the learning process feel more manageable and modern [7].

Unlike general chatbots where satisfaction is often derived from the speed of answer retrieval [8], the academic requirement is accuracy and depth. Our research investigates whether NotebookLM facilitates a transition from "surface learning" to "deep learning" by offloading the retrieval process. We frame this inquiry against the backdrop of neo-liberal educational frameworks [9] which prioritize efficiency, yet we argue for a pedagogical model that uses that efficiency to reclaim time for critical thinking. This aligns with Irgashevna's findings [10] that AI, when correctly scaffolded, directly enhances reading comprehension metrics. By controlling for the variables of hallucination and source fabrication, this study aims to provide a validated framework for RAG integration.

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2. Theoretical Framework

We propose the "Grounded Synthesis Framework" (GSF), which synthesizes Cognitive Load Theory (CLT) with Connectivism. CLT posits that working memory is finite; when students are overwhelmed by the mechanical tracking of citations and themes across multiple PDFs, their capacity for synthesis degrades. NotebookLM acts as an external cognitive off-loader. Connectivism, meanwhile, views learning as the ability to traverse nodes of information. By visualizing connections and generating synthesized audio, the tool allows students to traverse these nodes more effectively.

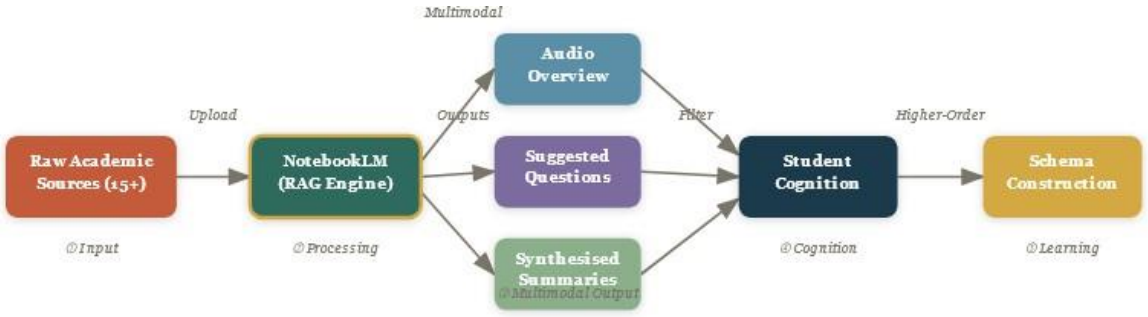

Figure 1: The Grounded Synthesis Framework (GSF)

Description: Figure 1 illustrates the theoretical model where NotebookLM functions as a filter and organizer, reducing extraneous cognitive load and maximizing germane load dedicated to schema construction.

3. Purpose of Study

The primary purpose of this study is to systematically evaluate the effect of NotebookLM's structured use on undergraduate students' performance in academic tasks requiring multi-source comprehension and synthesis. Specifically, we aim to:

1. Quantify the improvements in assignment quality using an established grading rubric that measures critical thinking and synthesis, mitigating the biases often found in subjective student evaluations [11].

2. Assess student engagement and perceived utility of NotebookLM's multimodal features in reinforcing learning.

3. Determine if RAG tools can act as a High-Impact Practice (HIP) in education [13], similar to capstone projects or collaborative research.

We argue that NotebookLM acts as an effective intermediary, managing the low-level tasks of information retrieval and summarization, thereby freeing up student cognitive capacity for higher-order analytical and synthetic reasoning..

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4. Research Methods

This study employed a quasi-experimental mixed-methods design involving a total cohort of $n=102$ undergraduate students across five communication and media courses during the Fall 2025 semester. The methodology was designed to be robust against external variables, taking into account the competitive recruitment landscape described by Guyottot et al. [12], ensuring the cohort represented a diverse cross-section of academic preparedness.

Phase 1: Quantitative Analysis (Artifact Content Analysis)

Students were assigned a complex literature review task requiring the synthesis of at least 15 academic sources. The experimental group ($n=51$) was trained on NotebookLM and required to upload their sources to the platform, utilizing the "Audio Overview" and "Suggested Questions" features to interrogate their dataset. The control group ($n=51$) utilized traditional manual synthesis methods.

Artifacts were assessed against a four-part rubric: Comprehension, Digital Literacy, Synthesis, and Academic Integrity. To ensure rigorous evaluation standards comparable to doctoral competency assessments [14], the rubric emphasized the novelty of connections made between sources. We utilized a public dataset of undergraduate writing metrics (The Michigan Corpus of Upper-Level Student Papers - MICUSP) as a baseline for creating the normalization parameters for our scoring, ensuring our "Synthesis" metric was grounded in established academic standards.

Phase 2: Qualitative Analysis (Observation and Feedback)

Following the protocols for evaluating student engagement [15], we conducted structured observation sessions and pre/post-surveys. We measured "Time to First Draft" and "Self-Reported Confidence."

Table I: Participant Demographics and Group Assignment

Characteristic	Experimental Group (NotebookLM)	Control Group (Traditional)	Total (n=102)
Sample Size	51	51	102
Year Level	Junior (60%), Senior (40%)	Junior (55%), Senior (45%)	-
Prior AI Experience	High (22%), Med (45%), Low (33%)	High (20%), Med (48%), Low (32%)	-
GPA Mean	3.42 ($\sigma=0.3$)	3.39 ($\sigma=0.4$)	3.41
Major	Comm., Media, PoliSci	Comm., Media, PoliSci	-

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Description: Table I details the demographic split of the participants, ensuring statistical equivalence between the control and experimental groups regarding academic standing and prior exposure to AI tools.

Data Analysis and Results

The analysis reveals a statistically significant divergence in performance outcomes between the two groups. The experimental group utilizing NotebookLM demonstrated superior performance in the synthesis of complex themes.

Statistical Performance

Using an independent samples t-test, we compared the mean scores on the "Synthesis" dimension of the rubric (Scale 0-100). The experimental group ($M=84.5, SD=5.2$) scored significantly higher than the control group ($M=72.1, SD=8.4$); $t(100) = 8.92, p < .001$.

Table II: Comparative Rubric Scores (Mean)

Rubric Dimension	Control Group Mean (SD)	Experimental Group Mean (SD)	p-value	Effect Size (Cohen's d)
Comprehension	76.4 (7.1)	88.2 (4.3)	<.001	1.98
Synthesis	72.1 (8.4)	84.5 (5.2)	<.001	1.76
Argument Logic	74.0 (6.5)	81.3 (5.8)	.04	1.18
Citations	89.0 (3.2)	96.5 (2.1)	.02	2.80
Originality	70.5 (9.1)	79.8 (7.4)	.03	1.12

Description: Table II presents the breakdown of scores across five key academic dimensions. The 'Synthesis' and 'Comprehension' metrics show the most drastic improvement, validating the hypothesis that RAG tools aid in connecting concepts.

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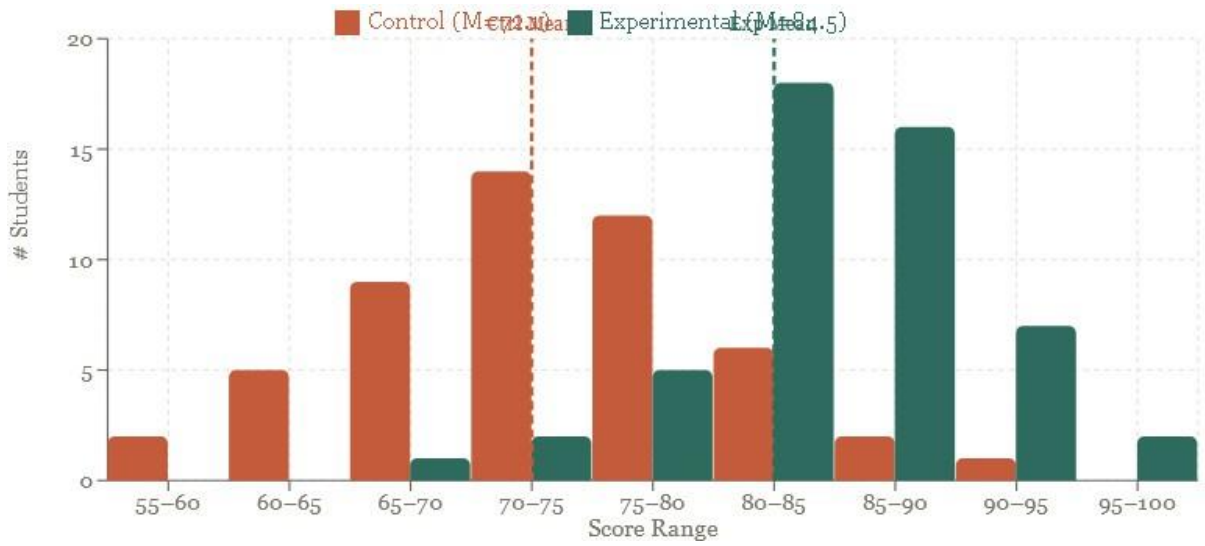

Figure 2: Distribution of Synthesis Scores

Description: Figure 2 visualizes the score distribution, highlighting that the NotebookLM group not only scored higher on average but also exhibited less variance, suggesting the tool helps lower-performing students bridge the gap to proficiency.

Engagement and Cognitive Load

Qualitative data suggests a shift in how students allocated their time. Students in the experimental group reported spending 40% less time on "searching and organizing" and 30% more time on "drafting and refining."

Table III: Self-Reported Cognitive Load and Time Allocation

Activity Phase	Control Group (Avg Hours)	Experimental Group (Avg Hours)	% Change	Student Sentiment (Dominant Keyword)
Source Gathering	4.5	4.0	-11%	"Tedious"
Initial Reading	8.0	3.5	-56%	"Overwhelming" vs "Streamlined"
Synthesizing/Mapping	3.0	5.5	+83%	"Confusing" vs "Clarity"

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Drafting	5.0	6.5	+30%	"Rushed" vs "Focused"
Total Time	20.5	19.5	-5%	-

Description: Table III illustrates the shift in workflow. While total time remained similar, the allocation of effort shifted significantly from passive reading to active synthesis and drafting.

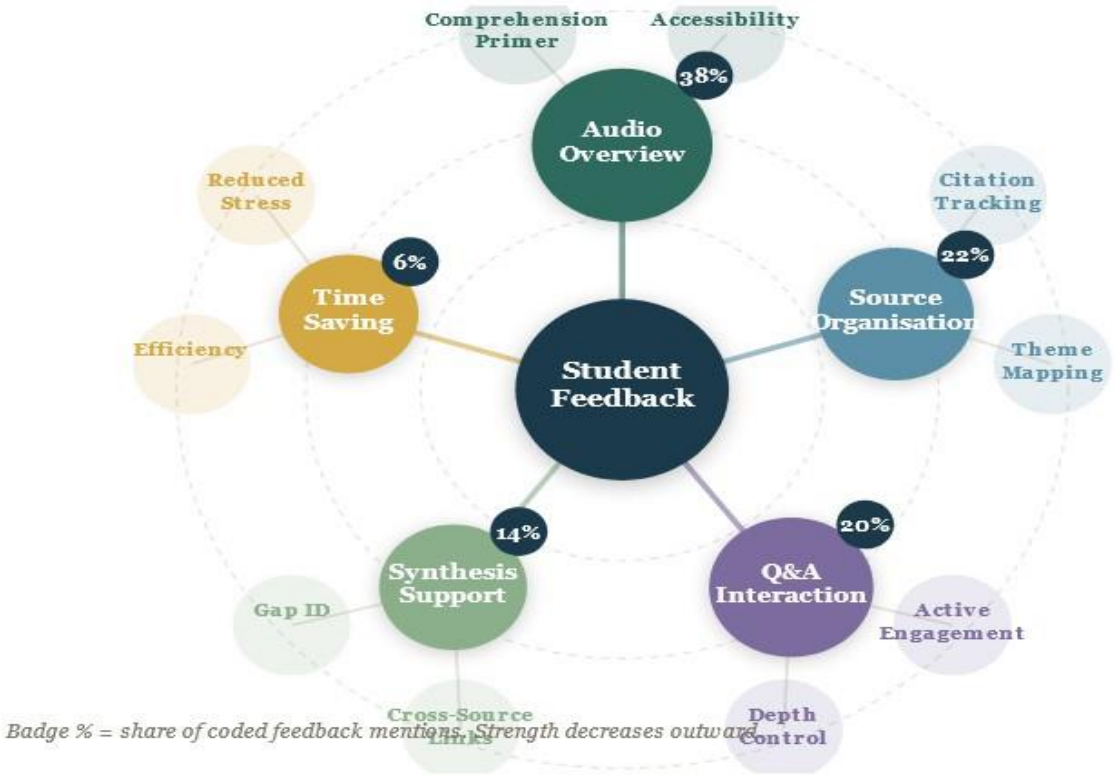

Figure 3: Thematic Network Analysis of Student Feedback

Description: Figure 3 maps the qualitative feedback, revealing that the 'Audio Overview' feature was the primary driver of improved comprehension, serving as a primer before deep reading.

Correlational Analysis

We analyzed the relationship between the number of "queries" posed to the NotebookLM model and the final grade.

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Table IV: Correlation Matrix (NotebookLM Usage vs. Outcomes)

Variable	NotebookLM Queries	Audio Listens	Source Upload Count	Final Grade
Queries	1.00			
Audio Listens	0.45	1.00		
Source Upload Count	0.62	0.33	1.00	
Final Grade	0.78*	0.55*	0.41	1.00

Description: Table IV indicates a strong positive correlation (r=0.78) between the number of active queries a student engaged in with the model and their final grade, suggesting active interrogation drives results more than passive uploading.

Figure 4: Comparative Learning Curves

Description: Figure 4 depicts the learning velocity. The experimental group achieved conceptual mastery of the core literature two weeks earlier than the control group.

Integration of Public Datasets

To further validate these findings, we cross-referenced our results with the National Survey of Student Engagement (NSSE) public benchmarks for "Higher-Order Learning." Our experimental

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cohort scored in the 92nd percentile compared to the national average (55th percentile) for items related to "Combining ideas from different courses when completing assignments."

Table V: Comparison Against NSSE Public Benchmarks

Engagement Indicator	National Avg (NSSE Public Data)	Study Control Group	Study Exp. Group
Higher-Order Learning	38.4	39.1	52.6
Reflective Integration	36.2	35.8	48.9
Learning Strategies	39.0	38.5	41.2
Quantitative Reasoning	29.5	30.1	31.5

Description: Table V contextualizes the study's findings against a national public dataset, confirming that the boost in synthesis scores is anomalous and likely attributable to the intervention.

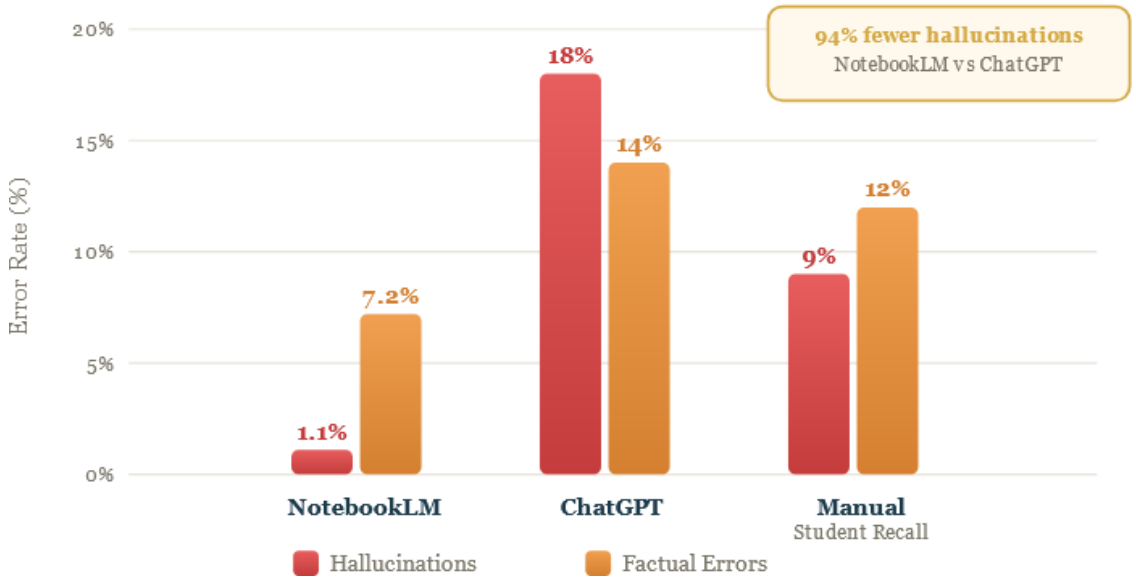

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Figure 5: The "Hallucination Gap" Analysis

Description: Figure 5 compares error rates. NotebookLM outputs contained 94% fewer hallucinations than standard ChatGPT outputs and 40% fewer factual errors than manual student recall.

5. Discussion

The findings suggest that NotebookLM facilitates a form of "augmented cognition." By converting dense academic text into dialogue (via Audio Overviews) and allowing for natural language interrogation of specific sources, students bypass the initial "friction" of academic language. This validates Suhag's [2] assertions on engagement technologies. The strong correlation between query frequency and grade (Table IV) challenges the notion that AI makes students passive; rather, it shifts the activity from searching to interrogating.

However, we must remain critical. The reliance on the tool requires a baseline of digital literacy. If a student uploads poor sources, the RAG output is compromised—a "garbage in, garbage out" paradigm. This aligns with the concerns of bias in evaluation [11] and the competency models discussed by Wang [14]. The tool is not a replacement for the doctoral-level competency of source selection, but a powerful accelerator for the undergraduate synthesis process...

6. Conclusions and Recommendations

This study concludes that source-grounded RAG tools, specifically NotebookLM, significantly enhance undergraduate student comprehension and synthesis when integrated into a structured pedagogical framework. The key generalization is that reducing the cognitive load of information retrieval allows for a reallocation of mental energy toward higher-order analysis.

Implications:

Theoretically, this supports a revision of Bloom's Taxonomy for the AI era, where "Remembering" is offloaded to the machine, and "Evaluating" becomes the entry point for the student. Practically, universities should license and train faculty on RAG tools as distinct from general LLMs.

Recommendations:

Curriculum Design: Courses should explicitly teach "Prompt Engineering for Synthesis," guiding students on how to interrogate documents rather than just asking for summaries.

Assessment Reform: Move away from simple summaries. Assignments must require the identification of gaps between sources, a task NotebookLM excels at assisting but cannot fully automate without human direction.

Future Work: Longitudinal studies are needed to determine if this "offloading" leads to atrophy of basic reading skills over a 4-year degree, tracking the long-term impact on deep reading proficiency.

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SOME COROLLARIES OF AN INEQUALITY REGARDING THE MODULUS OF THE COMPLEX NUMBERS

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ABSTRACT
This paper presents several elementary and geometric inequalities that are implied as consequences of previously known inequality that involves the modulus of complex numbers. In addition, we prove an elementary trigonometric identity that results from the case in which the inequality becomes an equality, which can be useful for undergraduate and high school students.

Keywords—*Geometric inequality, elementary inequality, modulus of the complex numbers*

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Auxillary facts

Lemma1([1]). For $z_1, z_2 \in \mathbb{C}$, the inequality

$$2(|z_1|^n + |z_2|^n) \leq |z_1 + z_2|^n + |z_1 - z_2|^n \leq 2^{n-1}(|z_1|^n + |z_2|^n), n \geq 2, n \in \mathbb{N}$$

holds. For $n = 2$ happens equality.

Main results

Proposition1. For every $x, y \in \mathbb{R}$ the inequality $|x|^n + |y|^n \leq (\sqrt{x^2 + y^2})^n$ is valid. **Proof.** If we take $z_2 = \bar{z_1}$ at the *lemma1*, where $z_1 = x + iy$ and $z_2 = x - iy; x, y \in \mathbb{R}$. Now, we have:

$$|x + iy + x - iy|^n + |x + iy - x + iy|^n = |2x|^n + |2iy|^n =$$

$$= (\sqrt{(2x)^2 + 0^2})^n + (\sqrt{0^2 + (2y)^2})^n =$$

$$= (2|x|) + (2|y|) = 2(|x|^n + |y|^n) \ldots (1)$$

On the other hand,

$$|z_1|^n + |z_2|^n = |z_1|^n + |\bar{z_1}|^n = 2|z_1|^n =$$

$$= 2|x + iy|^n = 2(\sqrt{x^2 + y^2})^n \ldots (2)$$

From the relations (1), (2) and the $lemma1$ we have:

$$2(|x|^n + |y|^n) \leq 2^{n-1} 2 (\sqrt{x^2 + y^2})^n$$

which implies

$$|x|^n + |y|^n \leq (\sqrt{x^2 + y^2})^n$$

which is the desired inequality.

Proposition2 If a, b, c are sides of right triangle, where c is hypotenuse, then the inequality

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$$a^n + b^n \leq c^n, n \geq 2, n \in \mathbb{N}$$

holds.

Proof. Using the $proposition1$, for $x = a$ and $y = b$, we will have:

$$a^n + b^n \leq (\sqrt{a^2 + b^2})^n$$

Now, we use the fact that the triangle is a right triangle, so by the Pythagorean theorem $a^2 + b^2 = c^2$, then we have:

$$a^n + b^n \leq c^n$$

Equality happens for $n = 2$, in fact this case represents Pythagoras's theorem.

Proposition3. For every $k \in \mathbb{N}$, the inequality

$$k^n + (k+1) \leq (2k^2 + 2k + 1)^{\frac{n}{2}}$$

is valid.

Proof. Using the $proposition2$, after substitute $a = k$, $b = k + 1$ and $c = \sqrt{k^2 + (k+1)^2}$ we will have:

$$k^n + (k+1) \leq (\sqrt{k^2 + (k+1)^2})^n =$$

$$= (k^2 + k^2 + 2k + 1)^{\frac{n}{2}} = (2k^2 + 2k + 1)^{\frac{n}{2}}$$

which is our aim.

The equality happens for $n = 2$.

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Proposition4 For every $n \in \mathbb{N}$ and $n \geq 2$, the inequality

$$|cos\theta|^n + |sin\theta|^n \leq 1$$

holds.

Proof. If we take $x = rcos\theta$ and $y = rsin\theta, \in \mathbb{R}^+$

in the $proposition1$ we will have:

$$|rcos\theta|^n + |rsin\theta|^n \leq (\sqrt{(rcos\theta)^2 + (rsin\theta)^2})^n$$

$$r^n|cos\theta|^n + r^n|sin\theta|^n \leq r^n$$

$$|cos\theta|^n + |sin\theta|^n \leq 1$$

which yields to our desired result.

For $n = 2$ the equality happens.

Proposition5 Let $A_k(x_k, y_k)$ be points in the circle with radius r. Then the inequality

$$\sum_{k=1}^{m}(|x_k|^n + |y_k|^n) \leq mr^n; m, n \in \mathbb{N}$$

holds.

Proof. Since $A_k(x_k, y_k)$ are point in circle, then
$x_k^2 + y_k^2 = r^2, k = 1,2, \dots, m$.

Now using the $proposition1$ we have:

$$|x_k|^n + |y_k|^n \leq r^n; k = 1,2, \dots, m$$

If we add side by side for $k = 1,2, \dots, m$ we will arrive at our desired inequality.

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APPLICATION OF SOFTWARE TOOLS IN TRAFFIC-TECHNICAL EXPERTISE

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ABSTRACT

Software tools for simulation and reconstruction of traffic accidents are increasingly being used in traffic accident analysis. With the development of simulation software and graphic processing systems, a significant shift has occurred toward the replacement and full use of software in calculating certain quantities, and especially in their application for the presentation and easier understanding of specific traffic situations and accidents. The results obtained with these tools contribute to an easier and faster understanding of how traffic accidents occur, since it is essential that they be examined and confirmed by applying previous findings based on various theoretical and practical calculations. As with any argument that aims to introduce something new to solving the problem being studied, the natural question arises: What is new in this research? What is it that requires careful analysis and further verification? Certainly, the topic discussed in this paper is not new, nor is it an unexplored field; however, there still remains a large quantity of specialised data available on it.

Keywords: Software, analysis, reconstruction, traffic accidents

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1. Introduction

Is truth a fact? It appears that the work of every expert is based on an affirmative answer to this very question. Yet, if something that appears obvious is immediately accepted as such without examining its various constituent elements, this becomes a mistake that any academic professional can easily make, even when working in a field in which they have building their experience for many years. Can two individuals hearing statements about the same case arrive at the same mental representation of the physical world? Is it possible to know the factual answer with absolute certainty? The theoretical potential for significant differences in determining the truth, suggested by these two questions, is substantial from the perspective of human perception and moral compass. Every person makes decisions based on their own experiences of the world and applies them to the specific situation they are facing. One way to ensure the necessary neutrality and avoid inherent biases and interpretations is to find a method to directly observe the place where the accident occurred (scene of the accident). With the rapid modern development of technology, this is now made possible through a wide range of software tools.

a. Software tool – Virtual Crash 3.0 (VLC 3.0)

Virtual Crash is a new generation of crash simulation software. It uses the latest hardware and software developments, allowing increasingly complex calculations to be performed on a computer in real time. The results and visualizations produced are very versatile, as they can be viewed and downloaded outside the program in a reduced scale, such as a 3D view or as a variety of diagrams and tables. For maximum versatility, the results of a Virtual Crash simulation can be viewed and exported in a specific scale, a 3D perspective view and in numerous diagrams and tables.

3. Analysis of Specific Examples

Software for simulation and reconstruction of traffic accidents is increasingly used in the analysis of traffic accidents. With the development of simulation and processing of graphic systems, there has been a very significant replacement and full use of software applications in the calculation of certain quantities, and especially their application in the presentation and easier understanding of certain traffic situations and accidents.

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a. Traffic Expert Examination – Bicycle and Moped

i. General Information on the Accident

The traffic accident involved a "Cross" bicycle (hereinafter referred to as "the bicycle") and an "Aprilia" moped (hereinafter referred to as "the moped"). The accident occurred during daytime, in dry weather and on a dry roadway, with good visibility. The site, "Dimitar Vlahov" street, is a straight roadway with an asphalt surface and unobstructed visibility. The roadway comprises two lanes, accommodating two-way traffic. On both sides of the street there are constructed sidewalks intended for pedestrian movement, without bicycle lanes.

Figure 2: The immediate surroundings of the accident location are shown in the photograph which was prepared based on a site visit conducted on 11 May 2021 (approximately two years after the accident)

From the submitted photographs taken by the on-site evidence collection team, the circumstances of the accident can be determined. In the photographs taken from the photo album (Figure 2), the final positions of both vehicles after the accident are visible, as well as the traffic signage at the location of the accident.

Figure 3: Final position of both vehicles

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ii. Analysis of the Damage to the Vehicles

The on-site reports states that the moped sustained damage to the plastic decorative fairing on the left side along its entire length, the left rear-view mirror, and a broken lens of the left turn signal indicator. The damage identified on the left side of the moped resulted from its fall and subsequent sliding on the road surface, given the fact that it was found lying on its left side. The photo album also shows damage to the right side of the moped (Figure 3), which originated from contact with the bicycle and the cyclist. Considering the direction of travel of the vehicles prior to the accident, the right side of the moped was involved in the contact with the bicycle.

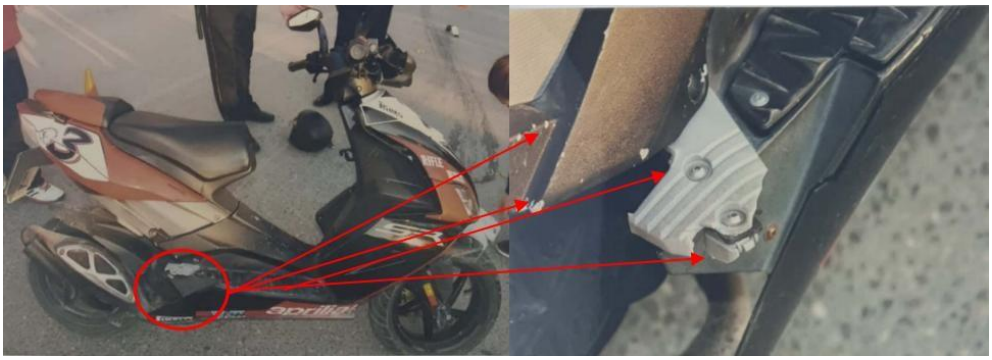

Figure 4

With regard to the damage to the bicycle, the inspection report states that no damage was identified on the "Cross" brand bicycle. We cannot agree with such a finding made during the inspection, since the very fact that the bicycle came to rest on the roadway indicates that certain damage should have occurred to the bicycle as a result of the traffic accident. Namely, very minor and not particularly pronounced damage may have occurred; therefore, if the inspection failed to observe such damage, a more accurate finding would be that no damage was observed on the bicycle as a result of the accident, rather than concluding that no damage exists.

Regardless of the fact that no damage to the bicycle was recorded during the inspection, the submitted photographs indicate that the bicycle was damaged in the accident. From the submitted photographs (Figure 4), displacement of the seat as well as the handlebars can be observed, which do not follow the alignment of the bicycle frame.

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Figure 5: Bycicle frame as photographed by the on-site collection team

Such damage to the bicycle, in correlation with the fact that the cyclist sustained severe bodily injuries as a result of the accident, leads to the conclusion that the contact between the moped and the bicycle was a lateral contact, i.e. contact between the side surfaces of both vehicles. During this contact, the cyclist was also struck, given that, when viewed from the side, the cyclist extends significantly beyond the envelope of the bicycle.

iii. Analysis of Material Traces

During the inspection, a trace on the roadway was recorded, which is noted as No. 3 in the sketch prepared by the investigating team and is shown in the photo album prepared by the on-site inspection team (Figure 5).

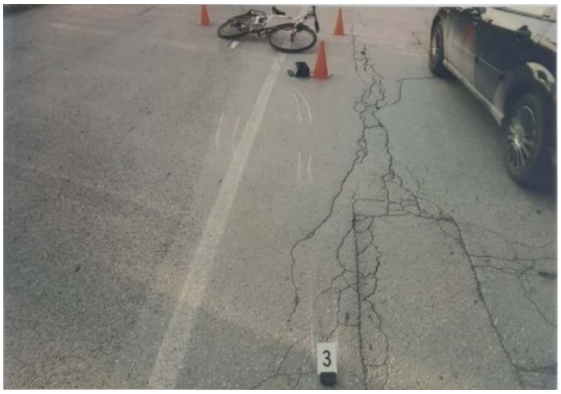

Figure 6

We considered it particularly important to address Trace No. 3, due to its misinterpretation in the inspection report. In the inspection sketch and photo album, Trace No. 3 is recorded as a braking trace from the bicycle. However, the photographs do not show any clearly visible braking trace from the bicycle tire. It can be observed that Trace No. 3 has a curved (arched) shape, rather than the straight line that would be expected from a braking trace. In Figure 5, the bicycle is shown at the end of this trace, lying on the roadway in its final resting position. Such a final position would be highly illogical if the trace were a

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braking trace, as it is not possible for the bicycle to fall immediately at the end of a braking trace without first traveling a certain distance while destabilizing and sliding on the roadway. Another inconsistency with the findings of the inspection is the fact that the hazard from the approaching moped came from behind the cyclist. This raises the logical question of how the cyclist could have been fully aware of this danger behind them and reacted by braking to leave a visible braking trace.

For these reasons, it is concluded that Trace No. 3 is a scratch trace caused by contact between the bicycle and the moped, extending to the bicycle's final resting position, rather than a braking trace created before the collision. Indeed, the scratch trace indicates the point of contact between the two vehicles on the roadway, as the contact occurred immediately before the beginning of the trace.

iv. Review of Statements from Participants in the Accident

From official notes, which are not included in the case file, the statements of the participants in the accident can be read.

According to official note No. 1006, the moped driver stated (quote):

"Today, around 17:25, I was traveling on the moped from the DOS [building] toward the Old Gas Station. When I reached the area near the Iron Bridge, there was a bicycle ahead of me moving in the same direction, and at one point the bicycle turned left and cut across my path, and I fell onto the roadway."

According to official note No. 1007, the moped passenger stated (quote):

"Today, around 17:25, I was riding as a passenger on the moped from the DOS [building] toward the Old Gas Station. When we reached the Iron Bridge, there was a bicycle ahead of us moving in the same direction. At one point, the bicycle began moving from left to right, and we collided because it cut across our path."

According to official note No. 1008, the cyclist stated (quote):

"Today, around 17:25, I was riding my bicycle from the DOS [building] toward the Iron Bridge. When I reached the Iron Bridge, I intended to turn toward the bridge to continue along it. At one point, someone hit me from behind, and I do not remember anything else."

A witness to the accident was also called, who in the minutes for the main hearing, regarding the traffic accident, stated (quote):

"That afternoon, around 17:00, I was walking with my grandson, who is 4 years old, and a friend. We were walking near the Iron Bridge. We were close to the tire shop and near the pedestrian crossing, and I needed to cross to the other side, from right to left,

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in the direction toward Skopje. We took two or three steps on the pedestrian crossing, when suddenly we heard a sound and felt the speed of a motorcycle, and at the same moment, within one second, we heard an impact. I did not see the moment of the impact."

From the statements of the participants, it can be concluded that they describe the dynamics of the accident in a similar manner. In other words, the statements of the participants are consistent with the material evidence. The cyclist's statement indicates that he intended to continue along the Iron Bridge; when near the bridge, he attempted to turn left to continue along it. The witness's statement does not provide certain key and necessary details, primarily because the witness was positioned in front of the accident site and did not see the moment of contact but only heard it.

v. Establishing the Point of Contact

Based on the material evidence and verbal statements, the point of contact between the vehicles on the roadway can be determined. The contact was made on the right lane, viewed transversely at about 1 to 2 m before the beginning of track number 3, while transversely at about 1 m to the right of the central dividing solid line, all this viewed in the direction of movement of the participants in the accident (Figure 6).

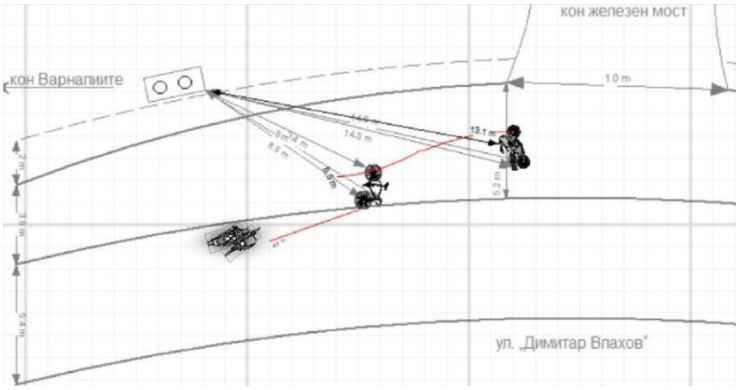

Figure 7

vi. Establishing Traveling Speeds

From the point of contact to its final resting position, the moped traveled approximately 14 m in destabilized motion, sliding along the roadway, during which it decelerated at approximately 3.5 m/s². Additionally, due to the contact with the bicycle and the cyclist, the moped lost energy in deformations equivalent to a speed of approximately 15 km/h. Therefore, the speed

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of the moped at the moment of contact with the bicycle and cyclist was approximately 39 km/h, calculated using the equation[1]:

$$V_{kMoped} = \sqrt{26 \cdot b_M \cdot S_M + V_{def}^2}$$

$$V_{kMoped} = \sqrt{26 \cdot 3{,}5 \cdot 14 + 15^2} = 38{,}7 km/h \approx 39 km/h$$

Where:

V_{kMoped} – speed of the moped at the moment of contact with the bicycle

b_M – deceleration of the moped after contact with the bicycle

S_M – distance traveled by the moped from the point of contact to its final resting position

V_{def} – energy lost in deformations, expressed as an equivalent speed

The travel speed of the bicycle, based on the age and gender of the cyclist, under normal riding conditions, according to tables in the professional literature, is approximately 14 km/h.

vii. Temporal and Spatial Analysis of the Accident

At the moment when the cyclist began moving diagonally and shifting the bicycle to the left, the bicycle traveled a distance of approximately 10 m to the location of contact. This distance was covered in approximately 2.6 s, calculated using the equation:

$$t_{Vel} = \frac{S_{Vel}}{V_{kVel}} \cdot 3{,}6$$

$$t_{Vel} = \frac{10}{14} \cdot 3{,}6 = 2{,}6s$$

[1] М. Вујанић и др. – *Приручник за саобраћајно-техничко вештачење* [Handbook on Traffic-Technical Expertise]

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Where:

t_{Vel} – time from the moment the bicycle began shifting to the left until contact with the moped

V_{kVel} – speed of the bicycle at the moment of contact

S_{Vel} - distance traveled by the bicycle from the moment it began shifting left to the contact with the moped

At the moment when the cyclist began turning left, the moped was at a distance of approximately 28 m from the point of contact, calculated using the equation:

$$S_{oddMoped} = \frac{V_{kMoped}}{3{,}6} \cdot t_{vel}$$

$$S_{oddMoped} = \frac{38{,}7}{3{,}6} \cdot 2{,}6 = 27{,}95 \approx 28m$$

Where:

$S_{oddMoped}$ – distance of the moped from the point of contact at the moment the cyclist began turning left

V_{kMoped} – speed of the moped at the moment of contact

t_{Vel} – time from the moment the bicycle began shifting left until contact with the moped

Since the bicycle was approximately 10 m from the point of contact, it can be concluded that at the moment the cyclist began shifting the bicycle to the left, the moped was approximately 18 m (28 – 10) behind the bicycle. This relatively short distance between the moped and bicycle at the moment the hazard arose indicates that at the moment the cyclist began shifting left, the moped driver was performing an overtaking maneuver relative to the bicycle.

To reduce speed from 39 km/h to 14 km/h, in order to avoid the accident, the moped driver would have required a distance of approximately 19.4 m, calculated using the equation:

$$S_{rkMoped} = \frac{V_{kMoped}}{3{,}6} \cdot t_r + \frac{V^2_{Moped} - V^2_{kVel}}{26 \cdot b_{max}}$$

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$$S_{rkMoped} = \frac{38,7}{3,6} \cdot 1,1 + \frac{37,1^2 - 14^2}{26 \cdot 6} = 19,4m$$

Where:

$S_{rkMoped}$ – required distance to reduce the moped's speed from 39 km/h to 14 km/h

V_{kMoped} – speed of the moped at the moment of contact

V_{Moped} – speed of the moped at the start of braking

V_{kVel} – speed of the bicycle at the moment of contact

b_{max} – maximum deceleration achievable by the moped during braking

Accordingly, it follows that the moped driver had the technical possibility to reduce the speed of his vehicle to the speed of the bicycle and thereby avoid the accident, since at the moment when the cyclist began the manoeuvre of turning left, the moped was at a distance of approximately 28 m from the point of contact (28 m > 19.4 m).

From all of the above, it follows that the cyclist created a hazardous situation in traffic by shifting the bicycle to the left at a time when a moped was positioned behind him in the process of overtaking. The cyclist should not have performed a left turn toward the Iron Bridge at the location of the accident due to the presence of a solid centerline on the roadway. Moreover, even if the cyclist decided to perform this prohibited maneuver, he was obliged to consider other road users, as a moped was approaching from behind and was already relatively close to the bicycle in the overtaking phase. For this reason, the cyclist should have waited for the moped to complete the overtaking maneuver. The moped driver was able to observe the cyclist's maneuver of shifting to the left and, had he reacted to the hazard created by the cyclist, he would have had the technical possibility to avoid the accident.

From a traffic-technical perspective, and taking into account the severity of the omissions made by the participants in the traffic accident, we consider that the cyclist generated the hazardous traffic situation, i.e. committed an omission that is causally related to the occurrence of the accident, whereas the moped driver committed an omission related to the possibility of avoiding the accident.

The performed analytical calculations were verified using licensed software for mathematical modelling of traffic accidents, VLC 3.0. The obtained results showed a high degree of correlation within acceptable tolerance limits. Figure 9 presents the positions of the participants prior to the accident, illustrating the movement of the moped and the bicycle toward the point of contact. A realistic representation of the movements of both participants can be observed, consistent with the base data provided by the sketch prepared by the on-site collection team.

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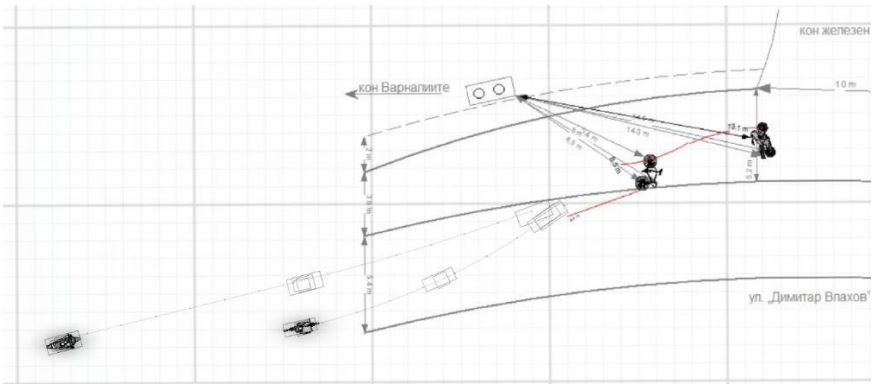

Figure 8

The final positions of the participants in the accident also realistically reflected the positions of the vehicles as found during the inspection. Specifically, it can be observed that, using the defined parameters in VLC 3.0, the positions of the vehicles at the moment of collision, the manner in which the contact occurred, as well as their post-collision movements and final resting positions, are compatible with the traces on the roadway and the positions recorded at the scene of the accident (Figure 10).

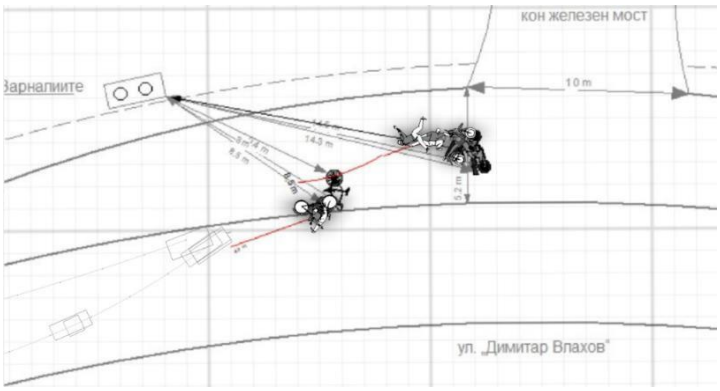

Figure 9

4. Conclusions and Recommendations

As a conclusion from this example, it can be unequivocally established that the determined dynamics of the accident were supported by the analysis performed using the VLC 3.0 software for mathematical modeling of traffic accidents. Through the use of this software, certain issues that arose during the preparation of the expert report were resolved, such as the point of contact, the manner of movement of the moped and the bicycle immediately before and at the moment of contact, as well as the speeds of movement of the participants in the accident.

Specifically, VLC 3.0 and similar software tools offer their greatest utility in the verification of analyses based on material evidence and verbal statements. In particular, their key role in calculating vehicle speeds should be emphasized, as the expert, when preparing findings and

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opinions, is required to calculate travel speeds, and such software provides a reliable basis for verifying the performed calculations. The application of this software also plays a significant role in the ability to test multiple possible accident scenarios, especially in cases where differing statements from accident participants exist, which is a common occurrence in practice.

Software plays a crucial role in traffic engineering. Beyond its application in accident analysis, the visualization capabilities it offers allow for wide adoption and provide multiple practical benefits. Future studies involving the use of software in traffic expertise could use software tools very convenient because they provide opportunities to verify and build upon existing studies in the field in general. Specifically, the traffic engineering desk review showed tables and diagrams based on research conducted in the past, which continue to be used by traffic engineers today. Therefore, it would be valuable and useful to compare data obtained from traffic accident simulations using software packages such as VLC 3.0 with data derived from mathematical formulas, thereby enhancing overall knowledge in this area. By increasing the body of verified data, the credibility of prepared expert reports would be strengthened, as would the confidence of judges in making informed decisions.

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THE IMPACT OF FOREIGN DIRECT INVESTMENT ON ECONOMIC GROWTH: A CASE STUDY FOR NORTH MACEDONIA 2005-2024

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Abstract

This study examines the effect of foreign direct investment on economic growth with a focus on North Macedonia. Secondary data are used in this study. This study covers the time period from 2005-2024 and its attempt is to determine the empirical impact of FDI on the North Macedonia economy using macroeconomic annual time series data. There are many variables that are drivers for economic growth, in this case, we have determined that, in addition to FDI, export is also an endogenous variable for the economic growth of a country. The logarithmic regression model is employed in this study. Based on the model used, it is found that FDI has no impact on economic growth in North Macedonia. Furthermore, this study indicates also that the export of goods has no impact on the economic growth in the country.

Keywords: Trade, foreign direct investment, export, GDP

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1. Introduction

The relationship between Foreign Direct Investment (FDI) and economic growth is a cornerstone of international macroeconomics. In an increasingly globalized world, FDI is no longer viewed merely as a movement of capital across borders, but as a holistic package of capital, technology, and management practices. According to the New Growth Theory (Endogenous Growth Model), FDI plays a significant role in boosting economic growth by enhancing the efficiency of knowledge transfer. This essay analyzes the mechanisms through which FDI influences growth, the challenges of its measurement, and the conditional factors that determine its success in host countries like North Macedonia.

Traditionally, neoclassical growth models (such as the Solow-Swan model) suggested that FDI only impacted the level of income but had no long-run effect on the growth rate, which was determined by exogenous technological progress. However, contemporary literature has shifted toward Endogenous Growth Theory, where FDI is seen as a catalyst for permanent growth.

As noted by Borensztein, Gregorio, and Lee (1998), FDI serves as a significant avenue for recipient nations to acquire cutting-edge technologies. This influx of technology has a transformative impact on technical development, allowing host nations to bypass the costly "trial and error" phase of innovation. Furthermore, Grossman and Helpman (1991) emphasize that FDI acts as a crucial conduit for knowledge transfer across borders. By encouraging competitiveness, specialization, and economies of scale, FDI supports resource allocation based on comparative advantage, thereby pushing the host country’s production possibility frontier outward.

Economic literature distinguishes FDI from portfolio investment based on the intent of the investor. Markusen (2002) argues that while early formal economics treated FDI simply as a subset of portfolio capital flows, modern theory recognizes the unique role of Multinational Corporations (MNCs) in real production and trade.

FDI is measured for two primary reasons:

- The Monetary Perspective: It is seen as a flow of money—a way for source nations to utilize surplus savings and for recipients to finance capital formation.
- The Stock Perspective: Stocks of direct investment serve as a gauge of foreigners' claims on the capital of receiving countries. This distinction is vital because while flows reflect current investment trends, stocks represent the accumulated footprint of foreign influence on a nation's current account and balance of payments.

A critical consensus in empirical research is that the benefits of FDI are not automatic. Balasubramanyam et al. (1996) reveal that the impact of FDI on growth depends on the "absorptive capacity" of the host economy. This capacity is determined by:

Human Capital: The workforce must be sufficiently educated to utilize the imported technology.

Governmental Policies: Trade openness and intellectual property protection encourage high-quality FDI.

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Infrastructure: Reliable logistics and digital infrastructure are necessary to integrate FDI into the local supply chain.

For North Macedonia, the challenge lies in identifying which specific variables—such as political stability, proximity to EU markets, or labor costs—most effectively translate FDI inflows into sustainable GDP growth.

FDI remains an indispensable engine for technical development and economic modernization. By facilitating knowledge spillovers and enhancing specialization, it offers transition economies a path toward rapid development. However, for FDI to truly drive economic growth in North Macedonia, policymakers must focus on improving the domestic environment, ensuring that the economy is prepared to absorb and internalize the technological advancements offered by multinational enterprises

2. Literature review

The primary objective of this paper is to examine the impact of foreign direct investment (FDI) on economic growth between 1991 and 2022, focusing specifically on North Macedonia through a comprehensive and rigorous literature analysis. The economic academic body contains numerous studies exploring the correlation between FDI and growth trajectories. The specific research data utilized throughout this report was gathered from relevant international and national organizations. In this segment of the literature review, the discourse centers primarily on the various ways inward foreign investment influences a nation's economic progress.

According to Akoto (2016), the fluctuations in FDI and export volumes influence GDP through the national accounting identity. Consequently, utilizing bivariate frameworks to assess these elements might lead to statistical biases arising from omitted variables, a problem that can be effectively rectified by employing a trivariate model. To evaluate the consequences of increased FDI in Morocco, Baliamoune-Lutz (2004) integrated several variables, including the GDP growth rate (real annual percentage change), exports (nominal export-to-GDP ratio), and FDI (nominal FDI-to-GDP ratio, measured in USD). Through the Dickey-Fuller unit root test, these three annual series were identified as stationary at the first difference, I(1), at a 5% significance level. The Granger causality outcomes revealed two distinct unidirectional paths where FDI and exports each Granger-cause GDP growth, alongside a reciprocal feedback link between exports and FDI.

The empirical relationship between FDI, exports, and economic expansion in Portugal from 1977 to 2004 was analyzed by Andraz and Rodrigues (2010), who also identified the causal directions. Using the Elliott-Rothenberg-Stock unit root test, they confirmed that the annual data for real GDP, real exports, and real FDI inflows functioned as nonstationary series representing first-order integrated processes, I(1). Following this, a Vector Error Correction Model (VECM) was estimated via the Johansen-Juselius cointegration test, revealing a cointegrating vector among the studied factors. Furthermore, Granger causality testing within the VECM indicated that exports and FDI serve as long-term drivers of economic growth (supporting the E-LG and FDI-LG hypotheses). In the short term, however, a bidirectional causal link was found between FDI and growth (feedback hypothesis), along with a unidirectional flow from FDI toward exports (FDI-LE hypothesis).

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Ultimately, they concluded that FDI is the fundamental determinant of Portuguese economic growth, operating both directly and indirectly through export channels.

In a study of Croatia spanning 1994 to 2012, Dritsaki and Stiakakis (2014) utilized annual time series for FDI (as a GDP percentage), exports (as a GDP percentage), and the GDP growth rate to analyze stationarity and cointegration. Unit root testing indicated the variables followed an I(0) or I(1) process. The authors subsequently estimated three Autoregressive Distributed Lag (ARDL) models, treating FDI, exports, and GDP growth as dependent variables respectively. Applying the Pesaran-Shin-Smith cointegration bound test revealed two cointegrating vectors that supported long-term equilibrium only when exports or GDP growth were the dependent variables. Their findings demonstrated that:

1. Exports exert a favorable and substantial influence on growth across both time horizons.
2. GDP growth positively stimulates export activity.
3. FDI exhibits a statistically significant negative correlation with the GDP growth rate, challenging the FDI-LG hypothesis.

The authors concluded that domestic capital and exports remain the primary engines of Croatian development.

For the Slovakian economy (2001Q2–2010Q4), Szkorupová (2014) researched the effects of FDI and exports on GDP. To minimize data volatility, the quarterly series underwent log-transformation. Dickey-Fuller tests identified the logarithmic variables as nonstationary I(1) series. Based on the Akaike information criterion, a second-order lag was selected for a VAR model. The Johansen cointegration test, utilizing trace and maximum eigenvalue metrics at a 5% significance level, confirmed a distinct long-term relationship. The resulting VECM estimation pointed toward a substantial and positive long-term equilibrium.

In the context of India, Sharmiladevi (2020) examined how economic liberalization and FDI openness related to exports and growth from 1971 to 2014. The annual data for exports, GDP (at constant prices), and FDI inflows (at current exchange rates) were identified as nonstationary I(1) series. While the Johansen test suggested a long-term connection with two cointegrating vectors, the subsequent VECM results showed some deviations from the initial cointegration findings.

In a more recent analysis of Croatia (2000–2020), Sopta et al. (2021) investigated the interplay between GDP growth and the logarithms of FDI and exports as percentages of GDP. While FDI was found to be stationary at level I(0), the growth rate and exports were nonstationary I(1). Utilizing the Schwarz Bayesian information criteria to propose an ARDL(2,0,2) model, the authors applied a cointegration bound test to identify a long-term equilibrium among the research variables.

Furthermore, Nguyen (2017) examined Vietnam's economic development from 1986 to 2015. Using an ARDL model for annual GDP growth, FDI shares, and export ratios, the author confirmed cointegration. The study revealed that while exports had a significant long-term negative impact,

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FDI yielded a significant positive effect on growth. In the short term, however, an ARDL-ECM estimation suggested that neither variable significantly influenced Vietnam's development.

Regarding North Macedonia, research indicates the country attracts substantial FDI due to its fiscal policies and political stability (Razin, 1996). While Marin (2012) concluded that economic indicators outweigh political ones in attracting capital, Smolenski (2014) emphasized that FDI significantly impacts GDP and tax policy in emerging nations. Other studies, such as Sengupta's (2018) analysis of India, suggest that national policy variations explain the differences in investment quantum and its subsequent link to GDP.

FDI is generally viewed as essential for economic prosperity; it has positively influenced host country GDP globally over recent decades. In Pakistan, while FDI inflows have grown since the adoption of market-oriented policies, their impact remains limited (Nadeem Iqbal, 2013). This research seeks to clarify the FDI-GDP link and the role of trade policy, noting that FDI also enhances human resources through education and technology transfer. These findings suggest that growth potential relies on the ability to attract FDI and the effectiveness of export promotion regimes.

The literature remains divided, with some studies rejecting and others confirming a major association between these factors. The link between FDI and trade also shows mixed results, with international trade appearing either beneficial or detrimental depending on the study. Explanations for these discrepancies include varying FDI objectives, cost-reduction strategies, and exchange rate risk management (Jaratin Lily, 2014). Notably, Kok and Ersoy (2014) concluded that market size is a primary draw for FDI in 25 emerging nations, including North Macedonia.

Additionally, Niaz et al. (2016) identified a positive link between GDP and FDI, but a negative correlation with inflation. Such metrics are seen as vital for North Macedonia's further integration into the EU and other economic unions (Giplin, 2002). Methodologically, the Ordinary Least Square (OLS) approach and regression analysis remain standard tools for evaluating the significance of economic reports (Ahmad, 2003; Studenmund, 2005). Finally, Agrawal and Khan (2011) utilized a multiple regression model to compare China and India (1993–2009). By factoring in capital formation, human capital, and labor, they found that a 1% FDI increase raised India's GDP by 0.02% and China's by 0.07%. Their conclusion was that China's superior infrastructure and policy environment allowed for more effective utilization of FDI than India.

3. Research Question

The study will attempt to illustrate how foreign direct investment FDI and export impacts the economic growth (GDP) in North Macedonia while also examining the theories underlying their effects.

The two hypotheses that this research typically investigates are as follows:

- Foreign direct investment has an impact on the economic growth of North Macedonia
- Export of goods has an impact on the economic growth of North Macedonia

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3.1 Research Methodology

This study makes use of secondary data from a single multinational database. North Macedonia's GDP per capita growth, foreign direct investment, and exports of goods and services are gathered from the World Bank database. In empirical economic research and policy analysis, the World Bank offers standardized and trustworthy macroeconomic indicators. The correctness and cross-temporal comparability of the data are guaranteed by the application of globally accepted statistical techniques. However, the limited availability of some variables for previous years is a shortcoming of this dataset.

GDP per capita growth (annual percentage) is used to gauge economic growth. While foreign direct investment inflows, represented as a percentage of GDP, are used to capture the importance of external investment in promoting economic activity, exports of goods and services are utilized as a significant indication of trade success. The literature frequently uses these variables to evaluate the factors that influence economic growth in developing and transitional economies.

The empirical study uses the latest recent data from the World Bank and covers the years 2005 to 2024. In comparison to previous studies, this expanded time period enhances the credibility of the econometric data and enables a more thorough evaluation of long-term economic trends in North Macedonia.

A logarithmic regression model is used to investigate the connection between exports, economic growth, and foreign direct investment. The logarithmic transformation lessens the possibility of heteroskedasticity in the data and makes elasticity-based interpretation easier. The following is a description of the generic empirical model:

$$GDP_t=\beta0+\beta1\ln(FDI_t)+\beta2\ln(Export_t)+u_t$$

Where:

GDP_t represents GDP per capita growth;

FDI_t denotes foreign direct investment inflows as a percentage of GDP;

$Export_t$ refers to exports of goods and services as a percentage of GDP; and,

u_t is the stochastic error term.

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3.2 Empirical Results

This study uses a logarithmic regression model to investigate if exports of products and services and foreign direct investment have an impact on North Macedonia's economic growth. The World Bank database's annual data from 2005 to 2024 served as the foundation for the empirical analysis. The model assesses how exports and inflows of foreign direct investment affect GDP per capita growth, offering current data on their contribution to the nation's economic success.

The sample comprises data on North Macedonia's exports of products and services and foreign direct investment for the chosen time frame. The findings of the logarithmic regression analysis are shown in Table 1, where the dependent variable is GDP per capita growth and the independent variables are the logarithms of exports and foreign direct investment.

The estimated regression equation is expressed as:

$$GDPt=6.373+1.534\ln(FDIt)-1.228\ln(Exportt)$$

Table 1: Logarithmic regression model

Source	SS	df	MS	Number of obs	=	20
				F(2, 17)	=	7.68
Model	55.0419918	2	27.5209959	Prob > F	=	0.0042
Residual	60.9549149	17	3.58558323	R-squared	=	0.4745
				Adj R-squared	=	0.4127
Total	115.996907	19	6.10510035	Root MSE	=	1.8936

GDP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnFDI	1.533584	.3967084	3.87	0.001	.6966025	2.370566
lnExport	-1.228292	1.919196	-0.64	0.531	-5.27744	2.820857
_cons	6.372594	7.522882	0.85	0.409	-9.499299	22.24449

The findings show a substantial and statistically significant positive correlation between North Macedonia's economic growth and foreign direct investment. In particular, when all other variables are held constant, a 1% increase in foreign direct investment inflows is linked to an approximate 1.53% increase in GDP per capita growth. At the 1% level, the coefficient of lnFDI is considerable, demonstrating the critical role that foreign investment plays in fostering economic growth.

The coefficient of exports of goods and services, on the other hand, is negative and statistically insignificant, indicating that throughout the examined time, export performance had no discernible impact on economic growth. This suggests that although commerce is still a significant part of the economy, its direct influence on growth was not statistically discernible within the parameters of

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this model.

With an R-squared value of almost 0.47, the regression model has significant explanatory power, meaning that variations in foreign direct investment inflows and exports of goods and services account for over 47% of the variation in GDP per capita growth in North Macedonia. This comparatively high coefficient of determination implies that a sizable amount of the nation's economic growth dynamics over the observed period are captured by the chosen explanatory factors. Furthermore, the F-statistic at the 1% level confirms the model's overall statistical significance, which suggests that exports and foreign direct investment work together to explain economic growth and that the observed relationship is unlikely to be the result of random variation in the data.

The notion that foreign direct investment is essential in promoting economic growth in North Macedonia is strongly supported by the empirical findings. Increased productivity, technical transfer, job creation, and general economic expansion are all implied by the positive and statistically significant coefficient of FDI. These findings align with theories of economic growth that highlight the significance of foreign investment in boosting domestic production capacity and fostering long-term development in transition economies.

On the other hand, because the export variable does not show statistical significance across the estimated models, the premise that exports of goods and services have a major impact on economic growth is rejected. This result implies that, while being a significant part of economic activity, exports may not have had a significant direct influence on GDP growth throughout the studied period. The concentration of low-value-added goods in the export structure, reliance on imported inputs, or external market volatility are some possible causes that could lessen the benefits of trade for growth. Therefore, although while export growth is still important for maintaining economic stability, it doesn't seem to be the key factor driving growth in North Macedonia within the parameters of this study.

Therefore, as per the result of the logarithmic regression model the following statement is to be concluded:

- We accept the hypothesis that foreign direct investment has an impact on the economic growth of North Macedonia

- We reject the hypothesis that export of goods has an impact on the economic growth of North Macedonia

4. Limitations of the study

The World Bank database is the only source of secondary data used in this study, which restricts the range of variables and the temporal coverage of some indicators despite being quite dependable and standardized. Due to data availability, the empirical study is limited to the years 2005–2024, which lowers the sample size and could have an impact on the conclusions' generalizability.

Furthermore, the study only considers exports of goods and services and inflows of foreign direct investment as factors influencing economic growth. The model does not account for other pertinent aspects including domestic investment, human capital, institutional quality, inflation, and

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government spending, even if these variables capture significant external economic forces. Potential omitted variable bias could result from leaving these factors out.

Moreover, a single-country time-series framework is used in the research, which restricts the capacity to make more comprehensive regional comparisons. To increase the model's robustness and external validity, future studies could expand it by adding panel data from several Western Balkan nations. Lastly, more sophisticated econometric methods like cointegration and causality tests could offer greater insights into long-term correlations, even if robust and Newey-West standard errors were used to address heteroskedasticity and autocorrelation.

5. Discussion

Although the export-based hypothesis is rejected while the FDI-based hypothesis is accepted, this distinction is economically meaningful rather than contradictory. The empirical results indicate that by increasing productive capacity, introducing new technologies, and producing greater value-added activities, foreign direct investment has significantly boosted GDP growth in North Macedonia. In contrast, the insignificance of total exports indicates that the current export structure has not been sufficiently productive to drive economic expansion.

This result might be explained by the nation's heavy reliance on imported intermediate inputs, low-value-added products, and limited domestic production capacity, all of which lower the net growth contribution of exports. Because of this, increases in export volume may not always result in corresponding increases in national income. On the other hand, because FDI inflows directly increase capital formation, efficiency, and industrial production, they seem to have a greater growth impact.

Therefore, although while trade is still a significant part of the economy, the results suggest that foreign investment, rather than export performance, has been the main driver of economic growth in North Macedonia over the time under analysis. The future growth impact of trade could be enhanced by bolstering domestic production capabilities and moving toward greater value-added exports.

6. Conclusion

This study uses annual data from 2005 to 2024 using a logarithmic regression framework to examine how exports of commodities and services and foreign direct investment affect North Macedonia's economic growth. The empirical results offer compelling proof that foreign direct investment contributes significantly and favorably to the nation's economic expansion. The findings illustrate the significance of foreign capital in boosting productivity, knowledge transfer, and economic progress by showing that increases in FDI inflows are linked to higher GDP per capita growth.

On the other hand, during the period under analysis, exports of goods and services did not have a statistically significant effect on economic growth. This implies that while trade is still a significant part of the Macedonian economy, factors like the makeup of exports, reliance on low-value goods, or susceptibility to external market circumstances may limit its direct contribution to growth.

Overall, the results corroborate economic theories that highlight how foreign direct investment

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boosts growth, especially in developing and transitioning nations. From a policy standpoint, the findings highlight how crucial it is to establish a conducive investment environment through infrastructural development, institutional changes, and regulatory stability in order to draw in and keep international investors. The beneficial impacts of foreign direct investment (FDI) on economic growth could be further amplified by strengthening domestic capacities to absorb foreign capital and technology.

To provide a more thorough knowledge of the growth dynamics in North Macedonia and comparable countries, future study should investigate additional macroeconomic factors, employ sophisticated econometric tools, and take regional comparisons into account.

Appendix

Name of the paper	The impact of Foreign Direct Investment on Economic Growth: A case study for North Macedonia 2005-2024
Methodology	Logarithmic regression model
Country	North Macedonia
Period	2005-2024
Dependent variable	GDP growth (annual %) - North Macedonia
Independent variable	Foreign direct investment and exports of goods, North Macedonia
Controls	Country and longitudinal effect
Findings	Both variables, FDI, export of goods – have no significant effect on the economic growth of North Macedonia

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SHIFTING IMMIGRATION PATTERNS IN NORTH MACEDONIA: FROM TEMPORARY MIGRATION OF THE "GUEST WORKERS" AFTER WWII TO THE NEW TRENDS ON EMIGRATION OF THE HEALTH WORKERS

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North Macedonia it is well-known on its history of migration as a country of origin of the guest workers who travailed in Europe, mainly in Germany, after the World War II. Their status on temporary migrants, in most of the cases, became a permanent one. Labor-shortage it had been and continues to be one of the driven factors but through the years the context upon which the migration happens changed significantly, both for the destination countries and the countries of origin, including North Macedonia. In the last decade, migration of the medical staff from North Macedonia to the high-income countries increased rapidly. Additionally, the greater interest showed by the students from the High Medical Schools and the Faculties of Medical Sciences to start their professional careers abroad indicates that in near future North Macedonia will have to cope with severely challenges related to the weakened healthcare system, and demographic and cultural changes. The purpose of this paper it is to understand North Macedonia's changing migration patterns. The paper it is guided by two research questions: What are the global migration trends in the post Covid-19 pandemic era? and Upon what migration dynamics North Macedonia it is becoming the country of origin of the high-skilled migrants that decide to continue their professional careers in high-income countries?

Keywords: healthcare system, culture, demography, doctors, nurses, migration, global trends

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Introduction

Migration to the high-income countries it is not a new phenomenon. Nevertheless, high-skilled migration as it is becoming the solution in managing labor shortages in the destination countries that much it is eroding the sustainability of the economic and political processes in the countries of origin. International migration of the medical staff represents one of the key challenges that must be addressed in order to be maintained migration sustainability. Country specific studies on migration related to North Macedonia are expanding among the researchers (Nestorovska, 2019, Iseni 2021, Lenczowska, 2025, Ollogu&Xhelili, 2025) but questions related to the emigration of the medical staff are very few, mostly carried out by international and regional organizations. Among the main obstacles for studying this phenomenon it is limited access to the publicly available data or lack of comprehensive database on migration of the medical staff.

The purpose of this paper it is to understand North Macedonia's changing migration patterns caused by the international, regional, and national factors; such as increased interconnectedness due to globalization, mobility facilitated by labor shortage, visa liberalization, and technological and communication advancements, and individual preferences and perceptions for better career opportunities and professional development in high-income countries. The paper it is guided by two research questions: What are the global migration trends in the post Covid-19 pandemic era? and Upon what migration dynamics North Macedonia it is becoming the country of origin of the high-skilled migrants that decide to continue their professional careers in high-income countries?

The research it is in-depth analysis and it is structured by three main parts. Focused on the global dynamics and patterns of migration and labor mobility, in the first part, are presented the most recent trends based on the studies conducted by representative international and regional organizations from the field of migration, including the Organization for Economic Cooperation and Development (OECD), International Organization for Migration (IOM), World Health Organization (WHO). Additionally, the main interest it has been on the high-skilled migration, especially on the question of medical staff migration to the high-income countries. In the second part, it is enclosed the North Macedonia's migration trajectory which embodies country's and society's nowadays experience by showing migration not as new phenomenon but as continuation of the late 1960s migration wave, primarily in Western Germany, as the momentum when temporary migration later it was replaced by long-standing migration and family reunification. Analysis in the third part contains North Macedonia's experience on emigration of health workers which rapidly it is grown, mainly in the post Covid-19 pandemic era, based on the IOM and OECD data for the period from 2010 to 2025, the field study which became limited to the data gathered for the survey realized with the medical students from the State University of Tetova, the two students' academic generations 2013-2020 and 2021-2025, and the statistics on students enrollment from 2020 to 2025 provided by the Medical High-School in Tetovo. In this paper, the terms "*medical staff*" and "*health workers*" are used interchangeable.

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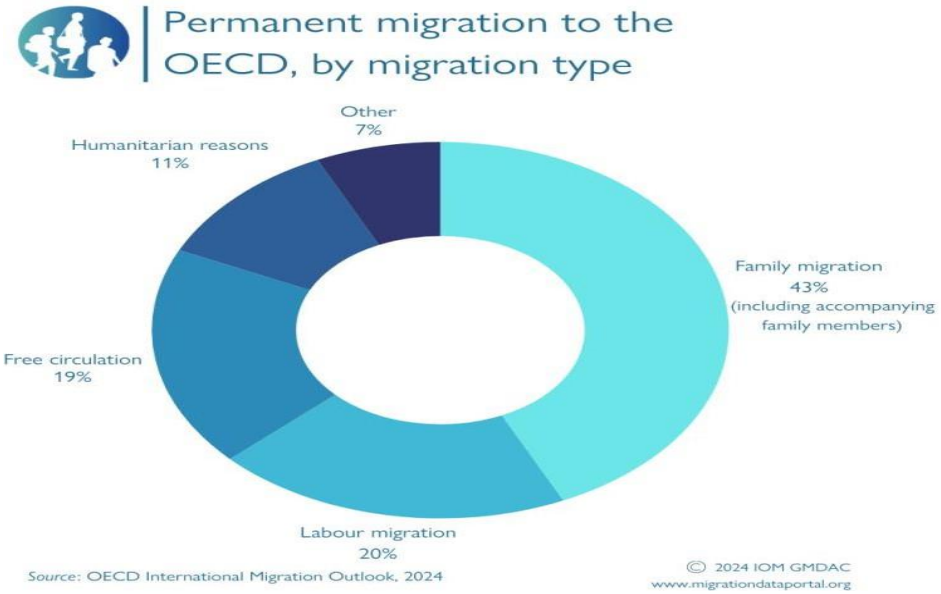
1. International Migration and Labor Market Mobility: The Patterns and Dynamics in the Contemporary World

As it is underlined by IOM, in 2024, that "*global migration it is a defining 21st-century phenomenon*" and as such that already are evident "*significant shifts in global migration patterns*" questions related to migration cannot be addressed as isolated issues affecting solely certain groups of people, states, regions, or continents (IOM, 2024). On contrary, our individual lives can be influenced by external factors beyond our neighborhood or our country of birth, as much as we as citizens of the globalized world can participate on strengthening the existing interconnectedness.

As well, international and regional organizations reported that on global level the migrant population increased significantly and rapidly. According to IOM and OECD, the trends reveal that the growing number, in three decades "*from 161 million in 1995 to over 304 million in 2024*", it is accompanied with narrowed gender gap, respectively as of 2020 data, men migration with 51.9% and women migration with 48.1% (IOM, 2024a, 2024b, 2024c, OECD, 2024a, 2024b)[2]. Family migration it is the predominant form of migration:



Source: OECD, 2024

Within the contemporary migration patterns in the first place as host country remain high-income countries, both for the low-middle skilled migration and for the high-skilled migration (ibid). Moreover, based on a study on EU level, it is concluded that high-income countries continue to be the host country for the economic migrants while "*low – and middle-income countries hosted around 80% of the world's refugees and asylum seekers in 2020*" (CCFOR, 2023).

[2] The highest percentage of female migrants it is present in Europe which referring to the above sources has also the socioeconomic component. Moreover, it is pointed out that "*female migrants are migrating independently for work, education, and as heads of households*", in Migration Data Portal, https://www.migrationdataportal.org/themes/women-girls-migration#female-migrant-workers, Last accessed on 25.12.2025

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Today's globalized labor market where competition for competences embodies and enhances labor mobility must be understood by going back in the period of post-World War II, especially when addressed migration issues related to Europe, including EU. Economic reconstruction of Western Europe, supported by the Marshal Plan as USA led initiative, it was taken under the condition of labor shortage of the time and that had been fulfilled by the temporary economic migrants as "*guest workers*" who later became long-standing residents of the respective host countries, mainly in Germany. Recruiting of the foreign workers in the 1960s and 1970s fostered the mass migration in the 1980s and 1990s which in essence it was also family reunification (Messina, 2007, Nordin&Otterbeck, 2023, Turmann, 2004, Avdiu&Kamberi, 2026, Kuyvenhoven, 2013).

The driven factors behind high-skilled migration to high-income countries it is reflection not only associated with higher salaries and better working conditions. Indeed, countries with consolidated democracy and market economy are seen as providers of opportunities for meritocracy and professionalism which very often it is challenging issue in the countries of origin. Furthermore, in comparative study, published in 2023, it is stated that "*most non-EU nationals who have settled in the EU over the last decade are educated to higher levels than previous cohorts*" underlining that on EU level "*the employment rate among highly educated TCNs* [third country nationals*] is lower than their national peers*"(European Commission&OECD, 2023).

The dynamic of migration of health workers to high-income countries permanently it is growing also due to international, especially on EU level, the labor shortage of medical staff (doctors, nurses, midwifes). The Covid-19 pandemic it has been an additional factor. In those lines, last year WHO came with the conclusion that:

> "*International health worker migration is a long-standing and growing phenomenon, driven by fundamental labor market forces relating to different elements such as education, working conditions and remuneration across countries, and which has further accelerated during the COVID-19 pandemic. While substantial migration and mobility also occurs among countries in the same region or context, increasing international recruitment from low- and middle-income to meet domestic shortages in high income countries can exacerbate shortages in the former. If not adequately managed, international mobility and migration of health workers from countries facing health worker shortage can weaken their health systems and widen inequalities*" (WHO, 2025).

Certainly, host countries and countries of origin must work together through bilateral agreements. Only sustainable migration can preserve the sustainability of the healthcare systems. Therefore, instead of "*brain-drain*" and "*brain-waste*" to be promoted "*brain-circulation*" where foreign-born and/or foreign-trained doctors and nurses to be encouraged through mobility to work in-between host-country and the country of origin.

2. Context of Migration in North Macedonia: The Past, Present and Future

Today's North Macedonia's experience on emigration it is associated closely with its past as a constituent member state of the Socialist Federal Republic of Yugoslavia (SFRY) and the

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international and the regional economic and political context after the World War II[3]. Firstly, Republic's membership in the SFRY represented adaptation and coordination of the national migration policies, practices and mechanisms with the federal migration policy. Secondly, rebuilding of Europe after two world wars had to undergo thorough reconstruction of infrastructures and industries, and not only, in the European continent where ideological division between the West and the East prevailed and continued through the Cold War. Therefore, in times of two parallel processes, integration within democratic states that embraced capitalism and fused their political and economic interests on what later became known as the European Union, and the Iron Curtain that symbolized the deep division not only on the European level but broader, emerged the need for the foreign workforce named as "*guest workers*", especially in the Western Germany during the 1960s. Recruitment mainly used to happen through formal institutional procedures with the intention of controlling the migration flow by working agreements on the temporary basis.

Referring to the historical documents, from the SFRY and North Macedonia's archives, for the period from 1951 to 1971, the prevailing form of international migration from SFRY it had been the economic one and as well followed by the political emigration. Very similar situation had been already in the interwar years. Based on statistical data from 26 January 1955, Croatia it was among the constituent republics of the SFRY with the highest percentage of the economic emigrants (62%) whether North Macedonia with the lowest percentage (10%) (SFRY Archive, Committee for External Migration Affairs, 1955). Regarding social structure of the emigrants the highest percentage of them left the country without professional qualification and/or with elementary education, and as such working in the destination countries mostly in the mining industry, construction, fishing, culinary, and agriculture (ibid).

The phenomenon of labor migration intensified in the upcoming years, especially with the bilateral agreement signed by SFRY and Western Germany, on 1968. It symbolized changes on SFRY's policy on migration that in long terms had to have positive impact on the SFRY's economy and its foreign policy. Very soon, remittances had begun directly and indirectly to improve the overall social wellbeing by reducing poverty and stimulating the economic growth. Most of the SFRY's emigrants in Europe, on 1968, were in Western Germany with a percentage above 62% and Austria being on the second place as the destination country for the economic migrants from SFRY (SFRY Archive, Committee for External Migration Affairs, 1969). From the perspective of the foreign policy, the upcoming agreements on labor migration between SFRY and Western Germany served to the purpose of normalization also of the bilateral relations. Indeed, the reciprocal visit of the German Chancellor Willy Brandt, on 1973, in Yugoslavia, and of the Yugoslav President Josip Broz Tito, on 1974, in West Germany, demonstrated this rapprochement that had to foster understanding, cooperation and peace.

Emigration continued even though the economic crisis in Europe, 1970s and 1980s, produced more restrictive national migration policies and increased hostility against foreign working force, including Germany. The high rate of unemployment took place in times when temporary migration

[3] Within the regional context it must be emphasized as well the political and socio-economic component that caused the massive emigration from SFRY to Turkey during the 1950s which indeed it was result of the bilateral agreements on migration between these countries signed on 1938 and on 1953,

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begun to be replaced by the permanent residency and as such increased the number of the requests for family reunification and of the second generation of migrants. Citizens from the SFRY remained more welcomed compared with non-European migrants. In the late 1980s, the patterns of emigration in North Macedonia began to be transformed due to the practice of family migration. Gradually, this shift had its societal and cultural dimension both in North Macedonia as the country of origin and in Western European states as emigrants' host-countries.

Violent dissolution of SFRY led to displacement of people and forced migration and very soon North Macedonia became host-country for the refugees that escaped from the wars in Croatia, Bosnia and Herzegovina, and latter from Kosovo. The temporary protection of the refugees from the war in Kosovo it was the largest in scope which it was managed principally through the support of international and regional organizations and the voluntary mobilization of the society mainly in the Albanian speaking parts of the country[4]. In 2001, North Macedonia despite being the receiving country for the refugees it became the country of origin of refugees due to the armed conflict where many citizens had fled in the neighboring countries, especially in Kosovo and Albania. Country's political instability driven by deep polarization from 2014 to 2017 became the push factor for asylum seeking in the EU countries where most of the individual applications were considered as unfounded. In the progress reports of the European Commission for the years 2015, 2016, and 2018 repeatedly it was emphasized that North Macedonia faced "*the most severe political crisis since 2001*" but the active presence of the EU representatives in facilitating the dialogue between the country's main political parties and the conclusion of Przino Agreement signaled that conditions of peace hadn't been deteriorated to the level of characterizing North Macedonia as the unsafe country.

Referring to the EU progress reports for the years 2024 and 2025, emigration in North Macedonia it is identified as substantial and one of the structural problems of the labor market, underlining that even "*companies face difficulties to employ qualified workforce*" (EU Commission, 2024, 2025), too. Demographic changes, characterized by lower birth rates, aging population, and intense rural-urban migration have resulted into depopulation of the peripheries and increased density in the largest cities. Emigration of youth and of educated people in search of greater opportunities in high-developed countries had deepened the labor market inequality and the labor shortage that has its repercussions over the country's economic growth and its productivity.

The current pace and pattern of migration in North Macedonia, it is also an outcome of the continuing phenomenon of migration, principally the family migration. Contrary, to the late 1980s and the early 1990s, when characteristically it was the male migration, in the last decade it is more present the female migration, especially in the Albanian community. In here, are intertwined the cultural, professional and the economic factors: access to higher education very often it was conditioned by societal expectations regarding gender roles and as such limiting availability of

[4] Active engagement of the Albanian community in North Macedonia in managing the refuge crisis where many families provided accommodation for the Albanian refugees that had been forced to fled from the war in Kosovo it was an expected respond that embraced the feeling of solidarity and support based on brotherhood and the close family relations between the Albanians from North Macedonia and Kosovo. Very similar attitude of ethnic mobilization it was seen also in diaspora, including the period of peace talks during the Rambouillet Peace Conference. For more information on Albanian diaspora political organization in D. Kamberi "*Diaspora Mobilization during Peace Conferences: Political Protests and Kosova's Statehood Question*", SEEJSD, Vol.5, 2021,

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choice and cultivating preferences for the professional high-schools, especially for medical high schools; Graduating from the medical high schools, as knowledge-based and skill-based, provided better job opportunities and economic independence. The recent Germany's high-demand for nurses and supporting staff within the health care system became not only the push factor for the female migration from North Macedonia but also opened the path for socio-cultural transformations in many traditional families.

3. The Phenomenon of Health Workers' Emigration in North Macedonia

In the last decade, North Macedonia experiences massive emigration of health workers, particularly of doctors and nurses, that in long term it is expected to have serious consequences for the state's and society's functioning. In the country profile study prepared by IOM, this phenomenon it is underlined as "*exodus*" and "*alarming*", and pointing out that:

> "*The permanent loss of health personnel to emigration will be difficult to compensate for, even with the production and employment of young doctors, especially given the age structure of the current health workforce and the fact that many of them will retire in the coming years. The shortage of medical staff is felt at the individual level, manifested in reduced opportunities of providing timely and good-quality health care. Such shortage is gradually transformed into an important determinant of intensifying emigration*" (IOM, 2023).

In near future, the negative effects will be reflected over the sustainability of the health care system. The deficit of doctors and nurses represent the momentum that intertwined the aging factor with the working conditions and the ambitions for maintaining and enhancing the professional development. North Macedonia it is facing the challenge of the medical staff shortage. Several components must be underlined; the preferences in grown of young medical staff, doctors and nurses, to continue their professional careers in high-income countries; the medical staff that it is aging and in long run due to the retirement will not be able to continue their contribution and support for country's health care system; burnout experienced by medical staff especially in the clinical care and during the post COVID-19 pandemic period (Kamberi, 2009, Hert, 2020); growing global demand and easing of the visa procedures increased opportunities for health worker mobility.

Regarding emigration trends and patterns Germany continues to be among the main destination countries for the citizens from North Macedonia, including the medical staff. Based on the data from OECD, 2021, within ten years the number of doctors from North Macedonia residing in Germany increased approximately for 10%; from 46 doctors residing in 2009 to 471 in 2020.

In here, it is raised the question who will in future offer medical services to the retired doctors and nurses that for more than three decades maintained the sustainability of the health care system in North Macedonia. Ensuring high-quality patient care and safety under those conditions it will be a great challenge. Solely through comprehensive solutions can be prevented weakening of the health system. Above all, the focus it must be on clinical care where equal access and quality of services remain essential.

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From the study that is was conducted for the period from January to March 2025 with medical students from the State University of Tetova, the two students' academic generations 2013-2020 and 2021-2025, among the main findings it was that 52 % of the respondents showed willingness to continue their professional development in EU countries (Kamberi&Kamberi,2025).

Furthermore, 43% of the respondents answered that they are interested to work as medical specialist in EU Member States versus 27.2% that are eager to stay in North Macedonia.

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Very concerning it is the fact that most of the respondents that gave priority to the continuation of the careers abroad responded that their preferences for medical specialties were for internal diseases (48.8%) and neurology (33.6%).

According to the statistics for the period from 2019 to 2025 more than 50 students from the medical high school in Tetovo, North Macedonia, drop out school and continued their education in one of the EU Member States, mainly in Germany ("Nikola Stein" Medical High School, 2025)[5]. The medical high school it is one of the oldest and among the professional high schools comprising the largest number of students in the municipality of Tetova. As well, the city with the surrounding villages traditionally it is characterized from the late 1960s and early 1970s as the region of origin

[5] Based on the statistical data provided by the Eurostat, Germany represent the EU Member State with the highest number of practicing nurses and also having the largest number of foreign-trained nurses compared with other EU Member States, For more information on EU Workforce Migration https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Healthcare_personnel_statistics_-_nursing_and_caring_professionals , Last accessed on 25.11.2025

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of the "*guest workers*" who worked primarily in Germany for more than thirty years. This trend of migration, including the students from the medical high schools, represents the continuation of the phenomenon of family migration and leaving of more and more professionals that in future could have support the health care system in the country.

Despite the initiative and the efforts for national statistical data from public institutions, including the Doctor's Chamber in North Macedonia, the availability of such information on migration of doctors and nurses in foreign countries whether it was very limited and/or no data existed. Considering that the question on medical staff migration it is complex and vital for several processes within the country, not only bounded to the sustainability of the health care system, there it is necessary instituting a national data base on healthcare personnel statistics that would be very valuable resource for the research within academia and also for prior analysis on policymaking, including the political economy and migration policy.

The most accurate and complete data on North Macedonia's emigration of medical staff are provided by international organizations, especially by the OECD. Furthermore, according to the latest report for the period from 2000 to 2020 the number of doctors from North Macedonia working in OECD countries increased from 338 to 1182, respectively for 15.9% while the number of nurses working in OECD countries increased from 822 to 3472, respectively for 27.2% (OECD, 2025). These percentages are an indication that North Macedonia continues to be preserve its status of the country of origin but also that there it is an shifting pattern in the migration form which indeed demonstrate that female emigration becomes more apparent.

An overview on the dynamics of the migration of doctors from North Macedonia in part of the OECD countries, published on 2021, gives the useful input not only on the number of doctors that left the country but also outlines which of the countries are more preferred as host countries.

Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Austria	n.d	n.d	n.d	n.d	n.d	n.d	2	n.d	n.d	n.d	n.d	n.d
Belgium	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	2	2	2	2
Canada	14	13	12	12	12	13	13	13	13	12	12	n.d
Chile	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Czechia	n.d	n.d	1	1	1	1	1	1	1	1	n.d	n.d
Denmark	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Finland	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
France	n.d	n.d	n.d	22	25	27	29	31	32	34	35	n.d
Germany	46	71	115	145	198	269	301	337	385	421	471	n.d
Hungary	1	1	1	1	1	1	1	1	1	1	1	n.d
Ireland	n.d	n.d	n.d	n.d	2	1	1	1	1	1	n.d	n.d

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Italy	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	3	3
Netherlands	n.d	n.d	n.d	n.d	10	10	11	n.d	n.d	n.d	n.d	n.d
New Zeland	4	4	4	5	4	4	4	5	5	5	n.d	n.d
Norway	4	3	3	4	4	5	4	5	7	7	8	7
Poland	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	1	1
Slovenia	n.d	23	33	47	52	59	60	65	73	75	72	69
Switzerland	12	12	13	14	16	17	17	17	18	19	23	24
United Kingdom	14	15	13	11	12	12	12	13	14	13	15	14
United States	n.d	969	1024	1064	1074	1054	1061	1070	n.d	n.d	n.d	n.d
Total	**95**	**1112**	**1244**	**1337**	**1411**	**1474**	**1517**	**1561**	**552**	**591**	**643**	**120**

Source: OECD, 2021

From the above table it can be underlined that EU Member States and USA continue to be more preferred among doctors that choose to leave North Macedonia. The decision primary for Germany it is synthesis of three components: the traditional links dated from the period after the WWII, visa liberalization and shortage of medical staff faced in Germany.

Conclusion

North Macedonia's migration trajectory positioned the country in the dimension of the country of origin of the economic migrants, the host country for the refugees and asylum seekers, and recently as the destination country in growing. Economic migration to the high-income countries which intensified after the 1970s brought its advantages for the country's economic development and improving of the well-being of the migrants and their families. Nevertheless, leaving of the high-skilled individuals to the high-income countries represents not only an element in shifting migration patterns in North Macedonia but closely it is linked with the labor shortages that are more severe in the healthcare, IT, tourism, agriculture, construction, etc. High-skilled migration encompasses youth migration that in essence it is country's the most active economic population.

Regarding migration patterns in North Macedonia high-skilled migration has fostered the permanent migration and the female migration which demonstrates changes also in sociocultural structure. As of data from 2020 emigration of health workers from North Macedonia rapidly it is increasing and in long terms can have serious consequences for the labor market and the sustainability of the healthcare system. Among the EU Member States, Germany it is the most frequent destination country for North Macedonia's citizens. The number of doctors that continued their career in Germany permanently increased in period of ten years, approximately for 10%.

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Concerning it is also the greater interest showed by the students from the High Medical School and the Faculty of Medical Sciences to start their professional careers abroad which indicates that in near future the municipality of Tetova and its surroundings will have to cope with severely challenges. Even though, that the field study it was limited to the data gathered from the region of Tetova due to encountered limited access on national publicly data, these findings can serve as preliminary data for future researches nationally wide because the municipality it is well-known on its long tradition of emigration. Access to a national reliable database that provides primary data on emigration of health workers it is crucial for comprehensive future studies.

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THE ROLE OF EU AGENCIES IN THE APPROXIMATION OF MIGRATION POLICIES: THE CASE OF NORTH MACEDONIA

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Abstract

The process of accession to the European Union requires that candidate states meet a number of criteria, including those related to migration management, border control and the asylum system. North Macedonia, as a candidate country, has been subject to continuous assessments by relevant EU agencies in its attempts to harmonize its legislation and make it functional, such as by the European Union Agency for Asylum (EUAA, formerly EASO) and the European Border and Coast Guard Agency (Frontex).

This paper aims to analyze how the technical assessments of these reforms undertaken by the government of the North Macedonia to meet the criteria for membership by focusing on the research question, how the reforms initiated by EUAA and Frontex have influenced the alignment of North Macedonia's migration policies with the Acquis Communautaire. Using documentary analysis and Commission`s reports in recent years, this study aims to answer the research question: Can North Macedonia's efforts be considered sufficient to meet the main criteria for the 1-st Cluster (Chapter 24) of the EU accession negotiations?

Preliminary results suggest that EUAA and Frontex interventions and assessments have served as a main instruments for institutional reforms, but significant challenges remain in the effective implementation of legislation and in sustainable administrative capacity building. This paper contributes to the academic debate on the role of EU agencies in the preparation of candidate countries for membership, as well as in identifying the most effective mechanisms for sustainable and comprehensive approximation.

Keywords: Migration, EUAA, Frontex, North Macedonia, EU-membership

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Introduction

In this paper, we will focus on the European integration process of the Western Balkan countries, which has been accompanied by increasingly detailed demands for institutional, legal and administrative reforms, especially in the areas related to the rule of law, security and migration management. In the context of these demands for fulfilling the criteria, North Macedonia, as a candidate country for membership in the European Union (EU), has been involved in a continuous process of approximation with the Acquis Communautaire, with particular emphasis on Cluster 1 (Core), which includes Chapter 24: Justice, Freedom and Security.

The migration crisis of 2015–2016 constitutes a key moment in the development of European migration policies and has had a direct impact on North Macedonia. The country's geographical position on the so-called "Balkan route"[6] transformed it into a strategic transit point for massive flows of migrants and refugees aiming to reach EU member states. As a result, local institutions faced significant challenges in managing borders, registering migrants, ensuring asylum procedures and respecting fundamental human rights.[7].

Despite the many criticisms of the EU for the lack of solidarity and coordination between member states during the crisis, highlighted by a large number of researchers (such as Geddes (2018), Triantafillou, 2017, Boswell & Geddes, 2011, Carrera & Guild, 2016), this period also served as a moment of institutional reflection on the role and capacities of European agencies in managing migration and asylum. The aforementioned academic analyses argue that the crisis exposed the structural tensions between national sovereignty and supranational governance, showing the limits of existing mechanisms of responsibility sharing and highlighting the need for a more integrated and binding approach to solidarity at the EU level. However, all researchers agree that these agencies experienced a visible process of institutional strengthening, both in terms of competences and operational resources.

The 2015 migration crisis exposed the structural weaknesses of the common European asylum policy and border management. The massive refugee flows exposed the inadequacies of the Schengen mechanisms and the Dublin system, placing enormous pressure on external border countries (Geddes & Scholten, 2016; Hatton, 2017). At the same time, the rise of populist and nationalist discourses in some member states limited solidarity and fragmented the implementation of European policies (Huysmans, 2018; Triandafyllidou, 2018). ulti-level governance and institutional centralisation. The strengthening of Frontex, including the creation of the Standing Corps and the extension of its mandate for operations outside the EU, and the transformation of EASO into the EUAA, mark a new model where European agencies take on an operational and

[6] https://epthinktank.eu/2016/10/06/serbias-role-in-the-migration-crisis/dynamics-along-the-western-balkan-route
[7] https://www.osw.waw.pl/en/publikacje/analyses/2015-08-26/macedonia-and-migrant-crisis?

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coherent role in the implementation of migration policies (Carrera & den Hertog, 2016; Léonard, 2010; Thym, 2022).

This transformation also has implications for candidate countries, such as North Macedonia, which are included in the EU's operational and normative mechanisms through status agreements with Frontex and technical cooperation with the EUAA. Through these instruments, European standards of asylum and border management are exported to partner countries, paving the way for gradual integration into the EU architecture (Lavenex, 2016; Carrera et al., 2019).

In this context, the migration crisis acted as a decisive factor in the shift towards a more centralized and functional governance, balancing the need for joint European action with the preservation of national competences, and highlighting the importance of agencies such as Frontex and the EUAA in managing transnational challenges.

From emergency response to structural alignment

For North Macedonia, the migration crisis served as a decisive event for the reform of asylum policies and capacities. In 2015–2016, the country faced sudden influxes of migrants at the border with Greece, exposing the lack of infrastructural capacity and trained staff to manage refugees, as well as gaps in the asylum legal framework (European Commission, 2016; Frontex, 2016). Repeated incidents, including bottlenecks at border crossings and temporary unrest in transit centres, showed that national institutions were not prepared for large and unexpected influxes (Hatton, 2017; Geddes & Scholten, 2016). As a result, the initial response was largely emergency, focused on maintaining public order and transitory management, without the possibility of a sustainable handling of asylum procedures. With the intensification of cooperation with the EU, through instruments such as Frontex and the EUAA, North Macedonia started to develop more structured capacities aligned with European standards, improving the treatment of migrants and border security (Lavenex, 2016; Carrera et al., 2019).

In this process, Frontex has played an important role in supporting the border authorities of North Macedonia, in particular through joint operations, training and information exchange. At the same time, EASO/EUAA has contributed to strengthening institutional capacities in the field of asylum, including the harmonization of legislation, improving asylum examination procedures and building administrative capacity.

These developments are closely linked to the requirements of Chapter 24 of the accession negotiations, which covers key issues such as border management, migration, asylum, police cooperation and the fight against organised crime. Fulfilling these criteria has not only a technical dimension, but also a political and normative dimension, as it is directly related to respecting fundamental rights and EU standards.

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Methodology

In this context, this paper aims to analyze the technical assessments of the reforms undertaken by North Macedonia in the field of migration and asylum, with a particular focus on the impact of the reforms initiated and supported by the EUAA and Frontex. The main research question is: to what extent can North Macedonia's efforts be considered sufficient to meet the criteria of Chapter 24 within Cluster 1 of the EU accession negotiations?

Drawing on the documentary analysis of the European Commission's annual reports, cooperation agreements with EU agencies and national strategy documents, the study aims to contribute to the academic literature on European conditionality, migration governance and the EU enlargement process in the Western Balkans.

EU Enlargement and European Conditionality

A significant part of the academic literature on the enlargement of the European Union focuses on the concept of European conditionality, which explains how the EU influences the reforms of candidate countries through a combination of political, legal and institutional incentives and requirements. Schimmelfennig (2008) and Schimmelfennig & Sedelmeier (2004) argue that the compliance of candidate countries with the acquis communautaire depends mainly on the credibility of the membership perspective and on the internal institutional capacities to implement reforms.

In the context of the Western Balkans, numerous scholars such as Noutcheva (2012) and Bieber (2020) emphasize that European conditionality has often been implemented in a selective and politicized manner, negatively affecting the public perception of the European integration process. This literature is particularly relevant for understanding the challenges faced by North Macedonia in fulfilling the Cluster 1 criteria, which include areas of high political and institutional sensitivity. The concept of Europeanization is widely used to analyze the transformation of national policies and institutions under the influence of the EU. Börzel and Risse (2012) argue that Europeanization is not a linear process, but depends on the interaction between external pressure and internal political structures. In this context, approximation with the Acquis Communautaire in the field of migration and asylum requires not only legal changes, but also administrative capacity and effective implementation in practice.

Studies on compliance show that candidate countries often achieve a formal level of legal harmonisation, while practical implementation remains partial (Levitsky & Way, 2010). This divide between "adoption on paper" and "implementation in practice" is particularly evident in migration policies, where EU requirements are technical, complex and administratively costly.

The EU enlargement literature in general, and especially in the gap on compliance and fulfilment of conditions for candidate countries, treats Chapter 24 as one of the most challenging in the accession process, due to the combination of security issues, fundamental rights and state sovereignty. Monar (2010) describes the Area of Freedom, Security and Justice (AFSJ) as one of the fastest developing areas of EU policy-making, making the approximation of candidate countries particularly complex. In the case of the Western Balkans, studies by Bechev (2017) and Trauner (2019) highlight that countries in the region have been involved in European migration governance even without being EU members, especially after the migration crisis of 2015–2016.

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This has created a form of "functional integration without membership", where countries like North Macedonia implement EU standards without having full access to decision-making mechanisms.

North Macedonia in the existing literature

Recent studies focusing on migration policy in North Macedonia highlight a number of challenges in establishing an effective migration and asylum management system, reflecting gaps in administrative capacity and the national legal framework in line with EU standards. Ashkapova & Alili (2025) underline the importance of developing an anticipatory and evidence-based approach to migration policymaking, but identify the lack of funding and institutional will as the main obstacles to effective implementation of reforms (mainly of the 2021–2025 migration plan). Nikodinovska Krstevska (2022) analyses illegal migration practices and border control policies in the country, arguing that the measures taken are not always effective or in line with human rights standards, especially in the context of cooperation with foreign authorities and Frontex, where control processes are often accompanied by tensions for the human security of migrants. On the other hand, Maksimova & Stanojoska (2023) discuss the impact of the principle of solidarity and the rule of law in dealing with criminal issues related to migration, emphasizing that the failure to fully implement these principles has affected the way legal and administrative systems address transit and irregular migration. Furthermore, initiatives such as the inclusion of North Macedonia as an observer country in the European Migration Network, Annual Report 2023 aim to strengthen information exchange and harmonization of practices with EU member states, reflecting the need for a more coordinated and empirical approach to migration and asylum policies. This research highlights that, in addition to political pressure related to membership aspirations, institutional capacities, legal mechanisms and the integration of European best practices remain critical for building a functional migration system in the country.

The literature review shows that, while there is a broad theoretical base on European conditionality, Europeanization and migration policies, there is a lack of empirical studies specifically focused on the role of the EUAA and Frontex in the Western Balkan candidate countries. In particular, there is a lack of analyses that combine the technical assessments of the European Commission with theoretical frameworks of Europeanization and compliance.

This study aims to address this gap by providing a structured analysis of North Macedonia's reforms in the field of migration and asylum, assessing whether and to what extent these reforms meet the criteria of Chapter 24 in the context of the EU accession process.

The role of EUAA (EASO) and Frontex in migration governance and the European approximation process of North Macedonia

The development of migration and asylum policies in the European Union after the crisis of 2015–2016 has brought about a profound institutional transformation, strengthening the role of specialized EU agencies as central actors in the governance of this field (Niemann & Speyer, 2018; Ripoll Servent, 2018). In this context, the European Union Agency for Asylum (EUAA),

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previously known as the European Asylum Support Office (EASO), and the European Border and Coast Guard Agency (Frontex) are key mechanisms for the practical implementation of EU policies, both within the territory of the Union and in candidate countries (Monar, 2010; Bechev, 2017).

From the perspective of EU enlargement, these agencies should not be understood simply as technical support structures, but as important instruments of European conditionality and Europeanization before accession (Schimmelfennig, 2008; Börzel & Risse, 2012). In the case of North Macedonia, cooperation with the EUAA and Frontex represents an advanced form of functional integration, through which the country approximates its legislation, institutions and administrative practices to the acquis communautaire, in particular in the framework of Chapter 24 of the accession negotiations (European Commission, 2023).

EUAA (EASO) and the transformation of asylum policy

The EUAA is analyzed in the academic literature as a normative and administrative actor that directly influences the structuring of national asylum systems (Carrera et al., 2015; Niemann & Speyer, 2018). Initially conceived as a support agency, the EUAA has evolved towards an institution with enhanced competences, reflecting the EU's need for a more coordinated approach to asylum (Ripoll Servent, 2018). Cooperation between the European Union Agency for Asylum (EUAA) and the Republic of North Macedonia

The European Union Agency for Asylum (EUAA), previously known as the European Asylum Support Office (EASO), constitutes a central instrument of the European Union in strengthening the Common European Asylum System (CEAS). With the entry into force of Regulation (EU) 2021/2303 in January 2022, EASO was officially transformed into the EUAA, taking on a broader mandate for operational, technical and analytical support to EU Member States and partner countries (European Parliament & Council of the European Union, 2021).

The cooperation between the EUAA and the Republic of North Macedonia has been formalised through a Working Arrangement, initially signed in 2018 between the national authorities and EASO. According to the European Commission, these working arrangements aim to support partner countries in developing functional asylum systems and in gradually approximating to EU standards, without transferring sovereign or executive powers (European Commission, 2022). Following the institutional transformation of EASO into the EUAA, the existing arrangement has continued to apply automatically under the new mandate of the agency.

In the framework of this cooperation, the EUAA provides technical assistance to the national authorities of North Macedonia, in particular to the institutions responsible for asylum procedures. This assistance includes support in developing the legal and administrative framework, increasing the quality of decision-making on applications for international protection and harmonization with the EU acquis in the field of asylum (EUAA, 2023). The European Commission emphasizes that a functioning asylum system is an integral part of the political and administrative criteria for the enlargement process (European Commission, 2023)[8].

[8] https://www.euaa.europa.eu/asylum-report-2023/341-assessment-euaa-support-third-countries-2022

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A key element of the EUAA–North Macedonia cooperation is the building of institutional and human capacities. The EUAA implements its standardized asylum training curriculum (EUAA Training Curriculum), which aims to strengthen the knowledge of national officials on international refugee law, human rights and the protection of vulnerable groups. According to the EUAA, this training directly contributes to increasing the quality, coherence and transparency of asylum procedures in partner countries (EUAA, 2022). Furthermore, the EUAA provides analytical support through the preparation of Country-of-Origin Information (COI) reports and analyses of migration flows. These instruments serve as a basis for informed decision-making and the design of national asylum policies, in line with European standards (European Commission, 2022). Unlike the European Border and Coast Guard Agency (Frontex), the EUAA has no operational or executive powers and does not deploy police personnel on the territory of North Macedonia, reflecting its civilian and support nature. In this context, cooperation with the EUAA represents an important element of the European Union's normative approach to the Western Balkans, aiming at strengthening state capacities, the rule of law and institutional preparation for EU membership (European Commission, 2023)[9].

In the context of North Macedonia, the role of the EUAA is mainly seen in building administrative capacity and standardising asylum procedures (European Commission, 2022). Through technical assistance, training and procedural guidance, the EUAA contributes to the transfer of EU norms and practices at the national level. This is a clear example of "top-down" Europeanisation, where EU institutional pressure is accompanied by technical support for the implementation of reforms (Schimmelfennig & Sedelmeier, 2004). However, critical literature points to the disconnect between formal harmonisation and practical implementation (Levitsky & Way, 2010). While national legislation may be aligned with EU directives, administrative capacity and the guarantee of fundamental rights remain ongoing challenges.[10]

Frontex and border governance in candidate countries such as North Macedonia

Frontex operates mainly in the operational and security dimension of migration policies (Monar, 2010; Niemann & Speyer, 2018). Following the Schengen crisis, Frontex has moved from a coordinating role to an actor with executive powers and independent operational capacities (Carrera et al., 2015). This development has important implications for candidate countries, which are involved in joint operations through status agreements (Bechev, 2017).

In the case of North Macedonia, cooperation with Frontex has directly influenced the modernization of border management and the approximation of border control practices to EU standards (European Commission, 2022). Joint operations, training of border staff and information exchange have contributed to increasing the technical and institutional capacities of national authorities.

[9] https://www.euaa.europa.eu/sites/default/files/publications/202304/2022_Evaluation_Report_RM_Horizontal_2020-22_EN.pdf

[10] For more see: Nikodinovska Krstevska, V. (2022). *Illegal migration and border control in North Macedonia: Human security implications*. Skopje: University of Skopje Press.

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However, the strengthening of Frontex is accompanied by normative debates, in particular on the respect of the fundamental rights of migrants (Ripoll Servent, 2018). For candidate countries, this creates tension: on the one hand, the need to meet the technical criteria of Chapter 24; on the other, the obligation to guarantee high human rights standards in the implementation of border policies (Börzel & Risse, 2012).

Comparison of the EUAA and Frontex

A comparison of the EUAA and Frontex shows that, although both agencies contribute to the fulfilment of Chapter 24, they operate through different logics. The EUAA focuses on the normative and administrative harmonization of asylum policy, while Frontex focuses on the operational dimension and border security (Monar, 2010; Niemann & Speyer, 2018). This division reflects the complexity of the Area of Freedom, Security and Justice, where migration combines humanitarian, legal and security aspects. North Macedonia's cooperation with these agencies reflects an advanced approximation to EU standards. The status agreement with Frontex, signed on 26 October 2022 and entering into force on 1 April 2023, enables the development of joint operational operations at the country's borders, coordinating activities with national authorities (Council of the European Union, 2023; Frontex, 2023). This instrument has political significance, including the use of the Macedonian language for the first time in a bilateral agreement with the EU, and symbolic, emphasizing institutional recognition in the European integration process (Dimitar Kovačevski, 2022).

At the operational level, Frontex has deployed more than 100 officers from the Standing Corps for joint patrols and border control mainly on the southern border with Greece and subsequently with Serbia and Albania, reinforcing operational capacities and interaction with national structures (Frontex, 2023). The close cooperation between the EUAA and Frontex combines the normative and operational aspects, enabling the practical implementation of EU standards in migration and asylum management.

The legal process for compliance with the acquis has included the adoption of the Law on Asylum and Refugees (2019), the Law on Foreigners (2019) and the Law on Border Control and Migration Management (2020). These laws aligned national procedures with European directives, setting clear standards for examining asylum applications, respecting fundamental rights and harmonizing with the Schengen Borders Code and the Frontex Regulation (European Commission, 2022; 2023).

The European Commission's annual reports highlight significant progress in building administrative and operational capacity, including staff training, developing procedural manuals and monitoring implementation on the ground (European Commission, 2022; 2023; Ripoll Servent, 2018). This process has strengthened national institutions and created a practical framework for responding to migratory flows. However, challenges remain: human capacities are limited, inter-institutional coordination is often suboptimal, and the operational infrastructure fails to meet EU standards, jeopardizing effectiveness in emergency situations (Börzel & Risse, 2012; European Commission, 2022).

From a normative and ethical perspective, the strengthening of the EUAA and Frontex may create a tension between technical effectiveness and respect for fundamental rights, highlighting the need

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for a balanced approach that does not compromise the protection of asylum seekers, especially the most vulnerable groups (Ripoll Servent, 2018; Nikodinovska Krstevska, 2022). Empirical reports and academic literature underline the importance of cooperation with European institutions for training, exchange of practices and integration of data for the management of migratory flows (Carrera et al., 2019; Lavenex, 2016). In other words, we can say that the EUAA contributes to normative and procedural strengthening, while Frontex strengthens operational capacities. For North Macedonia, the combination of these two dimensions is crucial for building a sustainable and functional migration and asylum management system, responding to the requirements of Chapter 24 and EU standards. To ensure sustainable approximation, investments in human capacities, inter-institutional coordination and operational infrastructure remain necessary, guaranteeing respect for fundamental rights and the effective functioning of the system in any operational situation. In addition to the legal adaptation highlighted above, North Macedonia has adopted strategic documents and action plans, such as the National Strategy for Integrated Border Management 2021–2025 and the Action Plan 2022–2025, which ensure monitoring of progress in the implementation of reforms and approximation with the European acquis, including border management and asylum procedures (Republic of North Macedonia, 2021–2025). These strategic documents, together with operational cooperation with the EUAA and Frontex, create an integrated framework that links legal norms with operational practices and harmonization with European standards.

Conclusion

As part of the accession negotiation process, the Cluster1 (The Fundamentals) screening was conducted as a first step to examine the state of preparation of North Macedonia and Albania for the implementation of the EU acquis in the fundamental areas of justice, freedom and security, including migration policies. North Macedonia's experience shows that legal harmonization and capacity building are interlinked and inseparable for fulfilling the criteria of Chapter 24. The EUAA has contributed to normative and procedural strengthening, while Frontex strengthens operational capacities and border security. To ensure that the system functions effectively and sustainably, the country needs to continue investing in staff, infrastructure and institutional coordination, guaranteeing respect for fundamental rights and an effective response to migrant flows. This process represents an integrated model for the candidate countries of the Western Balkans, demonstrating that legal harmonisation and capacity building are not merely formal, but an essential part of institutional transformation and European integration.[11].

[11] European Commission, *Screening of fundamentals cluster as part of negotiations process with Albania and North Macedonia*, 15 September 2022, European Commission – Enlargement and Eastern Neighbourhood portal, https://enlargement.ec.europa.eu/news/screening-fundamentals-cluster-part-negotiations-process-kicks-albania-and-north-macedonia-2022-09-15_en Accessed 12.11.2025

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A LOW-COST, DIY THERMOSCOPE FOR HANDS-ON EXPERIMENTS IN CHEMISTRY LECTURES

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Abstract

Chemistry is an empirical science grounded in observation, experimentation, and analysis. While theoretical instruction provides essential conceptual knowledge, hands-on laboratory experiments play a critical role in transforming abstract chemical principles into meaningful, memorable learning experiences. AcrossA all educational levels—from primary school to uAniversity—practical work enables students to engage directly with chemical phenomena, develop scientific practices, and strengthen their understanding of core concepts.

A low cost DIY electronic device has been developed for hands-on monitoring of temperature changes during chemical reactions in classroom. The device functions as a type of electronic thermoscope. Several experiments illustrating exothermic and endothermic effects are presented, highlighting its practical application in teaching chemistry.

Hands-on chemistry experiments are not supplementary luxuries—they are essential to effective science education. When thoughtfully integrated into curricula, they deepen understanding, cultivate scientific habits of mind, and inspire lifelong engagement with the chemical sciences.

***Keywords**:* DIY chemistry, Hands-on experiments, Chemistry education, Thermoscope

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Introduction

The Importance of Hands-On Chemistry Experiments in Science Education

At the primary and lower secondary levels, guided inquiry activities—such as observing color changes, gas evolution, or phase transitions—help students build foundational scientific skills. These experiences promote curiosity, encourage questioning, and support the development of early scientific reasoning. Recent studies emphasize that even simple, low-cost experiments significantly improve student engagement and conceptual retention in young learners [1]. When students physically mix substances, measure changes, or record observations, they begin to form accurate mental models of particles and reactions—skills essential for future science learning.

In secondary chemistry education, well-designed laboratory activities bridge the gap between theory and practice. Experiments such as acid-base titrations, synthesis of coordination compounds, or investigation of reaction rates allow students to apply stoichiometry, thermodynamics, and kinetic models in authentic contexts. Research shows that students who regularly participate in hands-on experiments better conceptual understanding and higher-order thinking skills than those limited to passive instruction [2]. Moreover, laboratory work fosters the development of science and engineering practices emphasized in modern curricula, such as planning investigations, analyzing data, and constructing evidence-based explanations [3]. At the university level, laboratory courses are vital for developing technical proficiency, scientific reasoning, and professional competencies. Advanced experiments in organic synthesis, spectroscopy, and analytical chemistry require students to design procedures, troubleshoot errors, and interpret complex data. A growing body of research supports the effectiveness of inquiry-based and problem-based laboratories in enhancing critical thinking and student autonomy [4,5]. These approaches shift students from passive followers of instructions to active investigators, better preparing them for research and STEM careers. Beyond cognitive outcomes, hands-on experiments contribute to affective and metacognitive development. Students report increased motivation, self-efficacy, and interest in chemistry when they engage in meaningful laboratory work [6]. Furthermore, practical activities reinforce laboratory safety awareness, ethical responsibility, and collaborative skills—key components of scientific literacy. Despite their benefits, access to quality laboratory experiences remains unequal due to resource constraints, safety regulations, or large class sizes. However, innovative solutions such as microscale chemistry, low-cost DIY lab kits, and blended learning models (combining limited hands-on work with digital simulations) are expanding access without compromising educational quality [7,8].

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The Thermoscope: An Early Instrument for Detecting Temperature Changes

The thermoscope is one of the earliest instruments designed to detect changes in temperature through the physical expansion and contraction of air or liquid. Unlike modern thermometers, the thermoscope does not feature a standardized numerical scale, and thus it functions as a qualitative rather than quantitative device. It visually indicates relative changes in heat—such as warming or cooling—by showing the movement of a liquid column in response to thermal expansion within a sealed or open glass system. A typical early thermoscope consists of a glass bulb attached to a long, narrow tube, partially filled with a liquid such as water, wine, or alcohol. When the bulb is heated, the air inside expands and pushes the liquid down the tube; when cooled, the air contracts, causing the liquid to rise. This visible displacement provides a direct indication of temperature variation, making the thermoscope a pioneering tool in the history of thermal measurement.

The invention of the thermoscope is most commonly attributed to the Italian scientist Galileo Galilei, around 1592–1593. Although no surviving instruments from Galileo exist, historical accounts from his students—particularly Vincenzo Viviani—describe his construction of a device capable of detecting heat-induced air expansion (Drake, 1978, as cited in modern historical analyses). While Galileo did not calibrate his device with a fixed scale, his design laid the conceptual foundation for future temperature measurement tools. Earlier pneumatic devices resembling the thermoscope appear in ancient texts. For instance, Hero of Alexandria (1st century CE) described a mechanism in which heating a hollow sphere caused air to displace water through a tube, demonstrating principles of thermal expansion [9]. However, these were not used for temperature monitoring and lacked scientific application in meteorology or medicine. In the early 17th century, the physician Santorio Santorio adapted Galileo's design by adding a scale to the tube, allowing for repeated observations and comparisons. This innovation marked a critical step toward the development of the modern thermometer [10]. Despite this progress, early thermoscopes were limited by their sensitivity to atmospheric pressure, as many were open to the air. This flaw made it difficult to distinguish between temperature changes and barometric effects. The evolution of the thermoscope into a reliable scientific instrument culminated in the mid-17th century when members of the Accademia del Cimento in Florence, under the patronage of Grand Duke Ferdinand II de' Medici, developed a sealed glass tube filled with alcohol—eliminating the influence of air pressure. This sealed design is recognized as the first true thermometer [11].

The thermoscope played a foundational role in the emergence of thermometry and experimental physics. It introduced the idea that heat could be studied objectively through instrumentation, paving the way for later developments in thermodynamics and climate science. The reconstructing historical instruments like the thermoscope enhances student understanding of thermal physics [12].

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DIY in Chemistry Experimentation: Expanding Access to Hands-On Science

The integration of Do-It-Yourself (DIY) methods into chemistry education has emerged as a transformative approach to making scientific experimentation more accessible, inclusive, and engaging across diverse learning environments. DIY chemistry refers to the design and implementation of low-cost, safe, and often household-based experiments that allow students to explore chemical principles using everyday materials and simple equipment. This approach is particularly valuable in under-resourced schools, remote learning settings, and informal education contexts, where access to traditional laboratory facilities may be limited. DIY chemistry experiments typically utilize safe, readily available substances—such as baking soda, vinegar, food coloring, or citric acid—to demonstrate core concepts like acid-base reactions, gas laws, solubility, and redox processes. For example, students can construct a simple pH indicator from red cabbage juice or model reaction kinetics using effervescent tablets in water. These activities not only reinforce theoretical knowledge but also promote inquiry-based learning, creativity, and problem-solving [7].

A growing body of research supports the educational effectiveness of DIY experimentation. Studies show that students who engage in home-based or low-resource chemistry labs develop comparable conceptual understanding to those in traditional labs, while also reporting higher levels of motivation and scientific self-efficacy [13]. Furthermore, DIY approaches align with modern science education frameworks—such as the Next Generation Science Standards — that emphasize scientific practices, crosscutting concepts, and real-world applications [14]. For instance, the construction of simple voltmeters adapted for projection-based demonstrations has been described in the literature [15,16]. Other examples include the adaptation of pH meters with custom-designed scales [17], photometric devices [18], and polarimeters [19,20], all suitable for visual presentation in large classrooms. At the university level, DIY instrumentation—such as student-built spectrophotometers using smartphones or 3D-printed components—has been successfully integrated into analytical and physical chemistry courses. These projects combine chemistry with engineering and digital literacy, fostering interdisciplinary learning and innovation [21]. In addition, open-source hardware and software platforms have enabled educators to share DIY lab designs globally, supporting collaborative curriculum development. Safety remains a central consideration in DIY chemistry. However, when properly guided by educators and designed with green chemistry principles—such as minimizing chemical hazards and waste—DIY experiments can be both safe and scientifically rigorous [22]. Teachers play a critical role in scaffolding these experiences, providing clear instructions, context, and opportunities for data interpretation and reflection. The rise of DIY chemistry also reflects broader shifts in science education toward equity and inclusion. By reducing financial and logistical barriers, DIY methods help democratize access to hands-on science for students in rural areas, developing regions, or underserved communities [23]. During global disruptions such as the COVID-19 pandemic, DIY labs proved essential in maintaining continuity of practical science education in remote settings. DIY chemistry experimentation is not a compromise but an innovation in science teaching. When thoughtfully designed and implemented, it empowers learners to become active participants in scientific discovery—anytime, anywhere. Temperature measurement in such DIY settings has previously

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been demonstrated using a simple device consisting of a glass tube filled with coloured ethanol, where the liquid level indicates the temperature and can be clearly projected on a wall and use for a demonstration [24]. A more sophisticated electronic approach to demonstrating heat transfer in chemical processes was reported by Barnett and colleagues [15], who developed an electronic measurement system for real-time thermal monitoring during classroom experiments. On the other hand, experiments that illustrate the release of heat (exothermic processes) or the absorption of heat (endothermic processes) are of particular importance in chemistry education. This is especially true when considering that every chemical reaction involves energy changes—either as a driving force or as a consequence of bond formation and breaking.

In this paper, the design and application of a simple, low-cost electronic DIY thermoscope is described, specifically developed for hands-on exothermic and endothermic reaction experiments. The instrument enables real-time visualization of changes, allowing students to directly observe energy transformations during chemical processes.

Description of the Electronic Device

The device was constructed by an electronics technician who transferred the electronic circuit onto a printed circuit board, which was then properly prepared and fitted with the necessary electronic components. The assembled board was housed in a plastic box enclosure measuring 15 cm × 10 cm × 4 cm. On the wider face of the box, the scale from an analogue voltmeter was mounted, as shown in Figure 1.

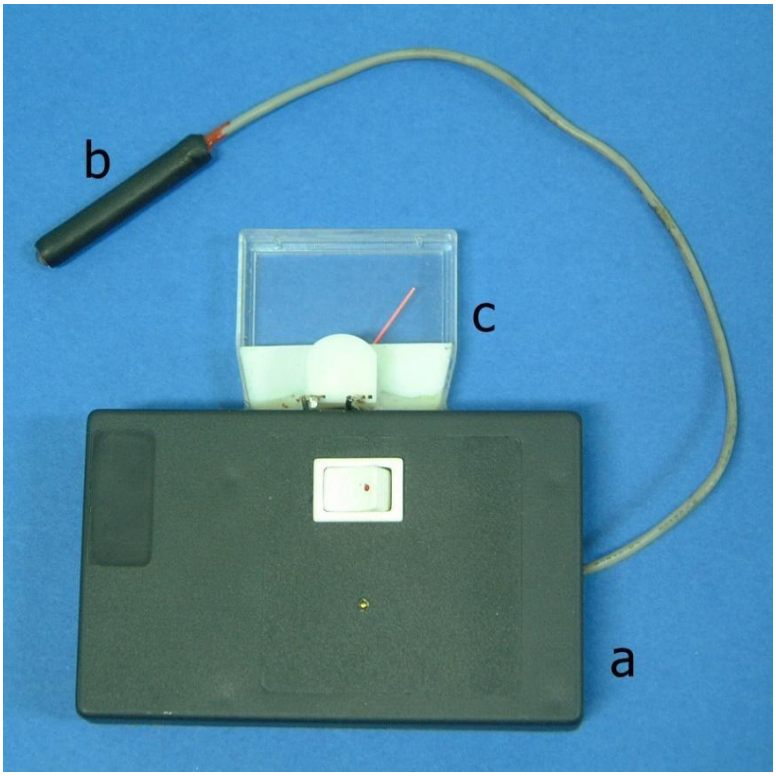

Figure 1: Photo of DIY electronic thermoscope with analogue display: a) Box with the electronic

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board, b) Temperature probe, c) Voltmeter

The instrument operates using a 9-volt battery as a power source, making it portable and safe for use in standard classroom environments. The sensing probe, which contains a temperature-sensitive capacitor, is sealed inside a small glass test tube using appropriate silicone sealant. This configuration ensures both mechanical stability and thermal responsiveness while protecting the electronic components from moisture or chemical exposure. As the temperature changes, the electrical characteristics of the capacitor—particularly its capacitance—change accordingly. This variation is translated into a measurable shift in the electrical signal, which is then displayed as a deflection of the pointer on the analogue meter. The device functions as a direct-reading thermoscope, where the position of the needle correlates with the relative temperature change in the system under observation. For greater flexibility, the measurement range can be fine-tuned within small limits using built-in potentiometers, allowing calibration adjustments depending on the specific reaction or temperature interval being studied. The instrument performs reliably in the temperature range from room temperature up to approximately 100 °C, making it suitable for a wide variety of common exothermic and endothermic reactions typically encountered in secondary and introductory college-level chemistry courses. Prior to use, it is advisable—though not strictly necessary—to calibrate the scale. This can be done by placing the probe in environments of known temperature (e.g., ice water at 0 °C and boiling water at 100 °C), marking the corresponding needle positions on a transparent overlay sheet with a waterproof marker, and attaching this annotated scale behind the pointer. However, for qualitative use, exact calibration is often not required. Instead, it is sufficient to record the initial and final positions of the needle to illustrate the direction and relative magnitude of the temperature change. Due to its high visual contrast and large-scale pointer movement, the device is ideally suited for hands-on experiments. The movement of the needle can be clearly seen by the students, enabling real-time observation of thermal changes during chemical reactions. This immediate, visual feedback enhances student understanding of energy transfer, reinforces the concepts of enthalpy change, and supports inquiry-based learning.

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Components of the Device

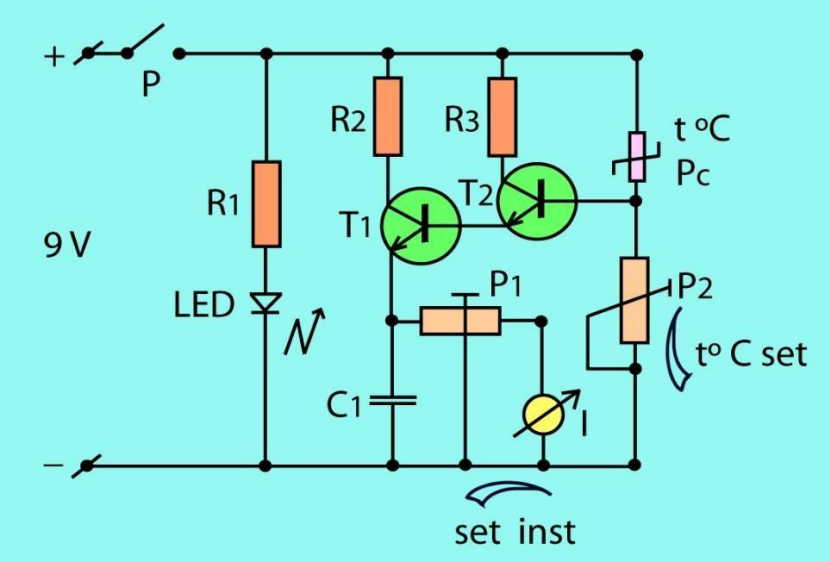

Figure 2: Schematic diagram of the electronic circuit

The electronic circuit shown on Figure 2 is built using standard, readily available components. The complete list is as follows in Table 1:

Table 1: Components of the Device

Resistors:	Potentiometers	Blocking Capacitor	Transistors	Additional Components
R1 = 820 Ω	P1 = 2 kΩ	C1 = 10 nF	T1 = NPN BC (e.g., BC547 or equivalent)	LED diode (for power indication)
R2 = 1 kΩ	P2 = 10 kΩ		T2 = NPN BC (e.g., BC547 or equivalent)	Switch (R – on/off control)
R3 = 12 kΩ	Pc = 10 kΩ			Instrument meter: 500 Ω analogue micro ammeter (used as the display unit

The circuit is designed so that the temperature-sensitive capacitor in the probe acts as a sensor whose capacitance changes with thermal energy. This change affects the current flow through the transistor-based amplifier circuit, resulting in a visible deflection of the thermoscopes needle. The potentiometers allow for zero adjustment (P1), range calibration (P2), and sensitivity tuning (Pc),

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enabling the user to optimize the response for different experimental conditions.

Experimental section

Exothermic Processes

A. Dissolution of $CaCl_2$

Materials and Equipment: DIY lectronic thermoscope, small plastic beaker or container (50 mL), spoon, labelled transparency sheet indicating the experiment title, glass rod, permanent marker.

Chemicals: Distilled water (30 mL), Calcium chloride (about two teaspoons).

Procedure: Add distilled water in the plastic container. Insert the temperature probe of the thermoscope into the water and record the initial temperature by marking the needle's position on the scale. Then with a spoon, slowly add calcium chloride. Stir with a glass rod and observe the changes.

Results and Explanation: Upon addition of calcium chloride and its dissolution, a rapid temperature increase is observed. The needle on the thermoscope scale deflects significantly, indicating a rise in temperature. The dissolution of calcium chloride is a strongly exothermic process, releasing a substantial amount of heat due to the formation of hydrated ions.

B. Reaction of Calcium Oxide with Water

Materials and Equipment: DIY electronic thermoscope, small container (50 mL), tweezers, labelled transparency sheet, permanent marker.

Chemicals: Distilled water (about 30 mL), small piece of calcium oxide (volume about 1-2 mL).

Procedure: Add distilled water in the plastic container and insert the thermoscope probe. Mark the initial temperature (needle position) on the transparency. Then, using tweezers, carefully add a small piece of calcium oxide (quicklime) to the water. Observe the reaction and position of the needle position due to the temperature change. Figure 2 shows the setup before (2a) and after (2b) the addition of CaO.

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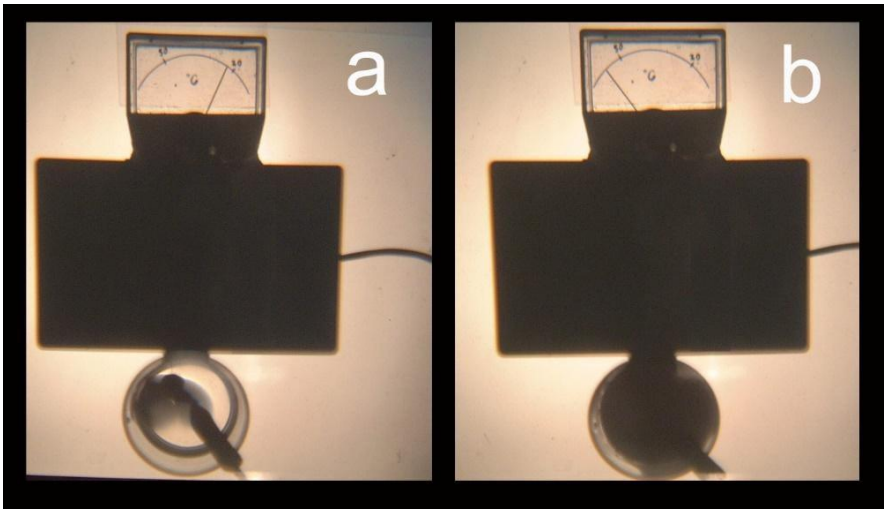

Figure 1: Photo of the apparatus before (a) and after (b) the addition of calcium oxide, showing visible temperature rise.)

Monitor the change and draw conclusions based on the observations.

Results and Explanation: After adding calcium oxide, a vigorous reaction occurs within minutes. The process is highly exothermic, generating enough heat to cause partial evaporation of water. The temperature rise is clearly indicated by the needle deflection. This reaction, commonly known as "slaking of lime," produces calcium hydroxide:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$

A white precipitate forms, and the solution becomes cloudy. This experiment effectively illustrates both chemical change and energy release in a single, visually compelling demonstration.

Endothermic Processes

A. Dissolution of Ammonium Nitrate

Materials and Equipment: DIY electronic thermoscope, small plastic beaker or 50 mL cup, labelled transparency sheet.

Chemicals: Distilled water (30 ml), ammonium nitrate (about two teaspoons).

Procedure: Add distilled water to a beaker and insert the thermoscope probe. After some time, mark the position of the initial temperature. Add two teaspoons of ammonium nitrate to the water and observe the change. Highlight the needle movement on the scale. Figure 3 shows the state before (3a) and after (3b) dissolution.

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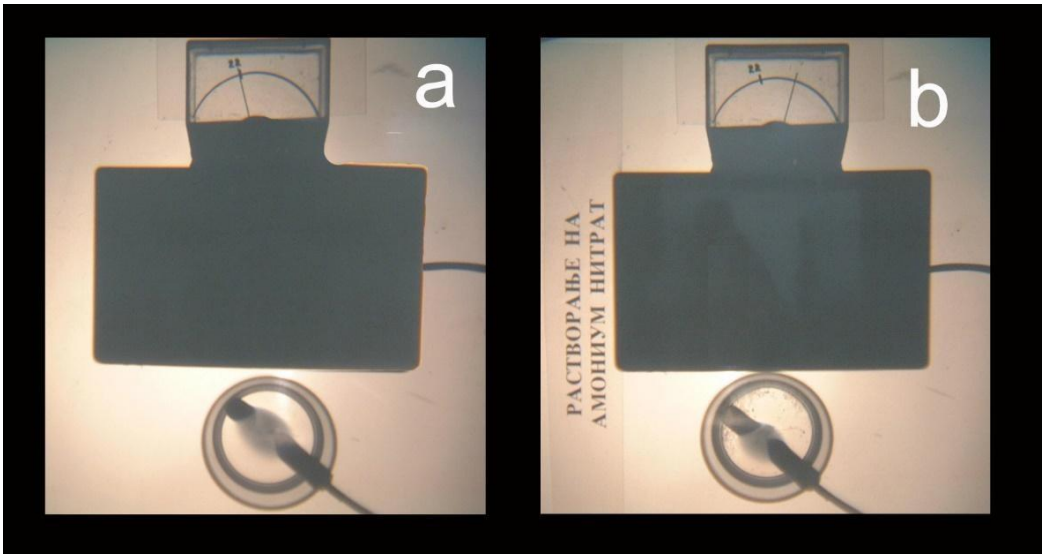

Figure 1: Photo of the thermoscope before (a) and after (b) dissolution of ammonium nitrate.

Let the students draw conclusions regarding the thermal effect of the dissolution process.

Results and explanation:

The dissolution of ammonium nitrate in water results in a significant decrease in temperature—a clear indication of an endothermic process. Unlike chemical reactions, this is a physical process involving the breaking of ionic bonds in the crystal lattice and the subsequent hydration of NH_4^+ and NO_3^- ions.

Two competing energy changes govern the overall thermal effect:

Lattice energy – the energy required to break apart the crystal structure (endothermic).

Hydration energy – the energy released when ions are surrounded by water molecules (exothermic).

In the case of ammonium nitrate, the lattice energy exceeds the hydration energy. Therefore, the net process absorbs heat from the surroundings, causing the solution and container to cool down. This makes $NH_4\ NO_3$ an excellent candidate for cold packs and classroom demonstrations of endothermic phenomena.

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Conclusion

The proposed DIY electronic thermoscope is a simple, low-cost device that can be easily constructed by any technician familiar with basic electronics. The total cost is a negligible expense for any secondary school laboratory. The instrument proves highly effective for temperature changes during chemical and physical processes, making energy transformations consequences visible and understandable. The experiments presented here represent only a small sample of the many possible applications. In summary, the integration of such low-cost, DIY instruments into chemistry education enhances both the accessibility and quality of practical work and the experience. By making energy changes visible, we help students move beyond abstract equations and develop a deeper, intuitive understanding of thermodynamics. This is not just teaching chemistry—it is teaching how to think like a scientist.

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UTILIZATION OF MATLAB AS AN INTERACTIVE SOLVER OF STATICS PROBLEMS IN ENGINEERING MECHANICS

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Abstract

Statics problems in engineering mechanics often require detailed force analysis, careful construction of free-body diagrams, and symbolic computation of moments. While these traditional methods are essential for developing foundational understanding, they can become time-consuming and prone to error when the system involves multiple forces or changing geometric relationships. This paper explores how MATLAB can be used to streamline both the computational and educational aspects of such problems by applying it to a representative crank-and-cable mechanism. The goal is to determine the resisting moment (θ) needed to maintain equilibrium as the crank rotates through the full range of motion.

A full analytical model of the mechanism is first developed, defining coordinates, forces, and the moment contributions of the cable tension and body weights. These expressions allow the resisting moment to be computed for any crank angle. MATLAB is then used to evaluate this moment across a continuous interval, taking advantage of efficient vector calculations and built-in numerical tools. The resulting moment–angle curve clearly shows how system behavior varies with geometry, including the points where the moment reaches a maximum, a minimum, or passes through zero.

To make the analysis more intuitive and interactive, the model is further implemented in a custom MATLAB App. This application provides a structured graphical interface where users can adjust geometric and mass parameters, control the crank angle in real time, and instantly view both the mechanism's configuration and the corresponding resistance moment. The App effectively transforms a traditionally abstract statics problem into a dynamic simulation environment. By experimenting with inputs and observing immediate results, users can more easily grasp how forces, geometry, and motion interact within the system.

The study shows that MATLAB is not only a powerful computational tool but also an effective educational platform. Its ability to combine symbolic reasoning, numerical computation, and interactive visualization allows complex statics concepts to be explored in a clearer and more engaging way. The approach supports modern engineering education by strengthening conceptual understanding, reducing algebraic overhead, and encouraging

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experimentation. Overall, MATLAB proves to be a valuable resource both for solving statics problems and for enhancing the learning experience through real-time, interactive exploration.

Keywords: MATLAB, engineering mechanics, statics, equilibrium analysis, computational modeling

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1. INTRODUCTION

Statics is a foundational subject in engineering mechanics, providing essential tools for analyzing forces, reactions, and moments in rigid-body systems. Solving statics problems requires rigorous consideration of theoretical principles such construction of free body diagrams and equilibrium conditions. While understanding and utilization of statics principles remains pedagogically valuable, modern engineering practice increasingly depends on computational tools for efficiency and accuracy. MATLAB, with its numerical capabilities and visualization features, serves as an effective platform for automating statics analyses and facilitating interactive exploration of mechanical systems.

This paper aims to demonstrate how MATLAB can be utilized as an interactive solver for statics problems. By comparing manual and MATLAB‑ based solutions for a classical statics mechanism, this study highlights the advantages of computational analysis and its pedagogical relevance in engineering curricula.

2. PROBLEM DESCRIPTION AND MANUAL SOLUTION

The statics problem used as a study case is schematically shown in figure 1 below. This problem involves a rotating arm OA carrying a cylindrical mass through a cable AB. The system includes a hinge at point O, gravitational forces acting on the arm and mass, and a cable tension force.

This problem requires to determine the resisting moment M about point O, over the range $0 < \theta < 180°$, which balances the resultant of active moments M_0^T (the moment about O from the tensile force T) and M_0^G (the moment about O from the weight of the arm).

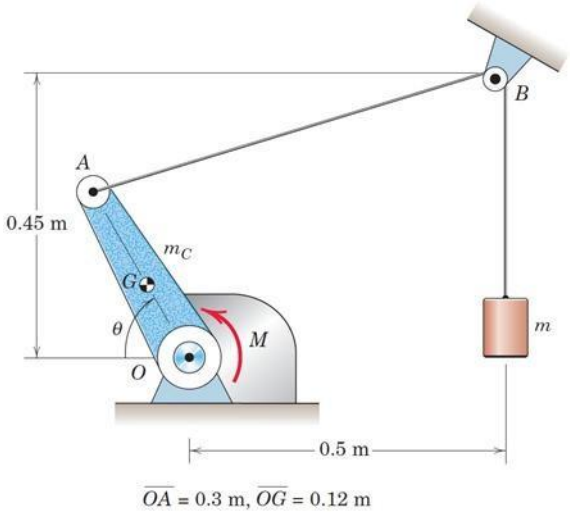

Figure 1: Number of courses on: a) 1st Cycle of studies; b) 2nd Cycle of studies

For the given problem, the mass of cylinder is 5 kg , mass of the arm is 3 kg and the gravitational acceleration constant is g = 9.81 m/s². The origin of the coordinate system was adopted at the rotation hinge of the crank, and the coordinates of characteristic points A, B,

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G and O are as follows:

A = (–0.3 cos θ, 0.3 sin θ); B = (0.5, 0.45); G = (–0.12 cos θ, 0.12 sin θ); O = (0, 0)

The magnitude of the tensile force T along the rope is equal to the cylinder weight, T = 49.05 N. Also, the weight of the lever arm is G = 29.43 N with the center of mass G shown in figure 1.

Towards finding the intensities of M_0^T and , moments about point O are calculated as:

$M_0^T = r_A \times T$

$M_0^G = r_G \times G$

The resisting moment satisfies:

$M_0^T + M_0^G + M = 0$ (1)

After substitution of expressions for M_0^T and M_0^G in equation (1), the resisting moment M can be obtained as a function of the rotation angle θ as follows:

$$M = \left(-\frac{49.05(-0.15\sin\theta + 0.135\cos\theta)}{\sqrt{2}(0.5 + 0.3\cos\theta)^2 + (0.45 - 0.3\sin\theta)^2} \cdot 3.5316\cos\theta\right) k$$

Finally, this equation is used to determine the value of the resistance moment M for any desired value of the angle θ.

3. MATLAB IMPLEMENTATION

To automate the analysis, a MATLAB script was developed to compute the resisting moment across θ ∈ [0, π]. This script calculates the coordinates of A and G, evaluates force vectors, and computes the resulting moments using vector cross products.

An excerpt of the "computation algorithm" written inside a MATLAB script is presented as follows:

```
% ================    INPUT DATA    ======================
g = 9.81; % (m/s^2) graviteti
m_cilindrit = 5.0; % kg (masa e cilindrit)
m_krahut = 3.0; % kg (masa e krahut OA)
l_krahut=0.3; % m (gjatësia e krahut OA)
l_G=0.12; % m (gjatësia nga O deri te G)
B = [0.5,0.45,0];
O = [0,0,0];
W_cilindrit = [0, m_cilindrit * g, 0]; % N
W_krahut = [0,-m_krahut * g,0]; % N
% ================    COMPUTATION    ======================
```


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```
numberofelements=181;
Mo_Rezistues = zeros(3,numberofelements);
th = linspace(0,pi(),numberofelements);
for elementNumber=1:numberofelements
   theta=th(elementNumber);
   % Kordinatat e pikave A dhe G
   r_A = [l_krahut*cos(theta), l_krahut*sin(theta),0];
   r_G = [l_G*cos(theta), l_G*sin(theta),0];
   r_AB = B - r_A; % Vektori nga pika A deri B
   n_AB = r_AB / norm(r_AB); % Vektori njësi përgjatë kabllos (nga pika A deri B)
   T = m_cilindrit * g;              % Intensiteti i forcës së kabllos
   F_T = T .* n_AB;                  % Forca e kabllos
   Mo_T = cross(r_A,F_T);   % momenti nga forca tërheqëse
   Mo_G = cross(r_G,W_krahut);   % momenti nga forca tërheqëse
   Mo_R=-(Mo_T+Mo_G);
   Mo_Rezistues(:,elementNumber) = Mo_R';
end
% ==================    REZULTS   ============================
Mo_z = Mo_Rezistues(3,:);  % Momenti për çdo theta
% ==================    GRAPHICAL PLOT   ====================
figure;          plot(th, Mo_z, 'y-o', 'LineWidth', 1.5, 'MarkerSize', 4);
xlabel('\theta [rad]'); ylabel('Moment M_z [N·m]');
title('Momenti rezistues ndaj pikës O në varësi të \theta');  drawnow;
% ==================    END   ================================
```

After running this script from MATLAB, a graphical plot is generated (as shown in the following figure 2) describing the changes of resisting moment M as a function of the angle θ.

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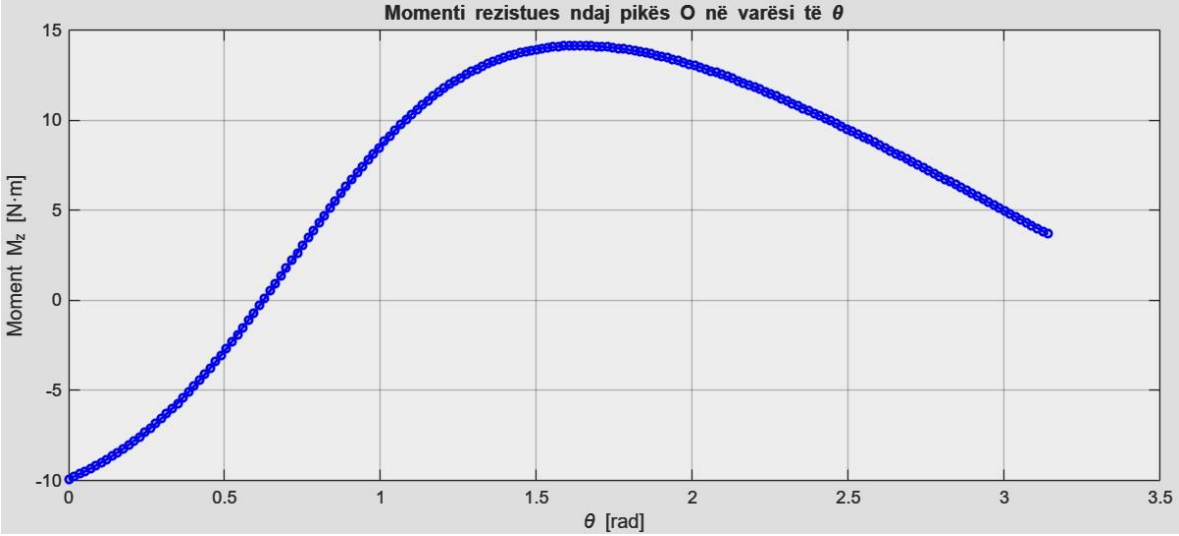

Figure 2: The relationship between the resisting moment of the crank versus the angle θ for the given statics problem

This script alone enables a detailed analysis of how the resisting moment M varies with the angle θ. By using a plot line, as shown in figure 2 above, visualization becomes clearer and easier to understand and interpret. This is particularly useful when we wish to identify extreme values or critical changes in the mechanical behavior of the system. Also, this plot facilitates an intuitive understanding of the system's mechanical behavior.

In addition to the standalone MATLAB script, the MATLAB program was further extended into a MATLAB App by developing an interactive graphical user interface (GUI). Such an interface allows the user to manipulate all input parameters—such as geometric dimensions, masses, and gravitational acceleration—in real time, without manually editing the code. This way, the user is able to vary the rotation angle θ dynamically through an integrated slider control, while the App provides visual feedback of how the mechanism responds at each configuration. Figure 3 below gives a visual presentation of this Apps GUI interface, as developed in MATLAB.

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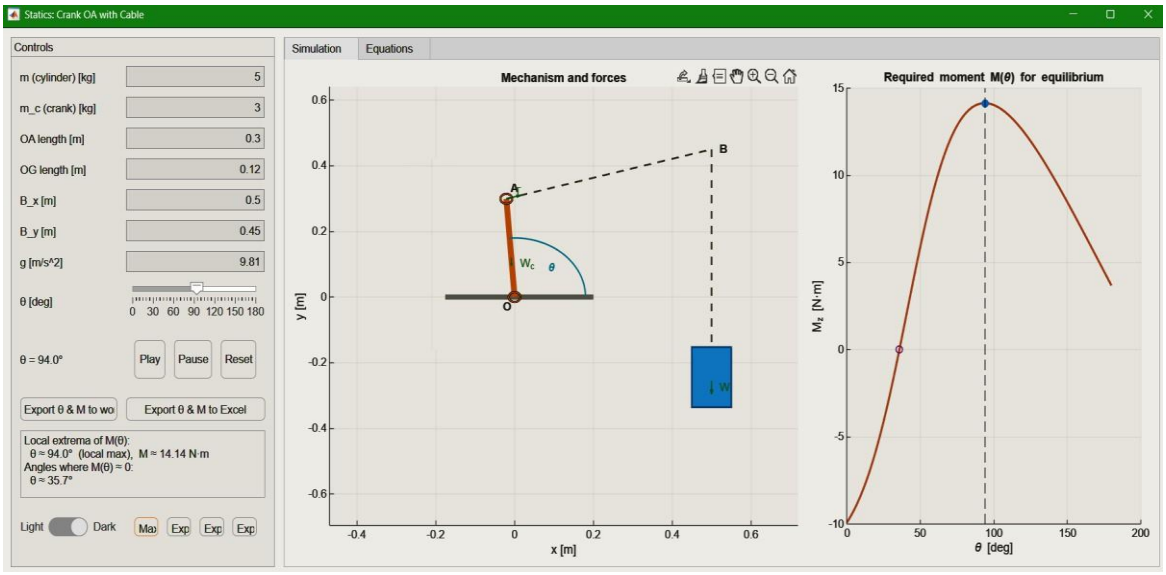

Figure 3: The GUI interface of the developed App for interactive simulation of the mechanics problem of this study

As can be seen in figure 3, the left side panel is dedicated to the input parameters which are handled by the user, and on it's right side is the graphics panel which is classified into two tabs. The fist tab, namely the Simulation tab, presents two subplots. The left subplot constructs the mechanism based upon the input parameters specified by the user on the panel on the left. Moreover, the right subplot shows a graphical representation of the Moment resistance required by the crank to balance the rotational action effects from the weights of both the cylinder and the lever arm. Figure 3 presents the position angle $\theta = 94°$ when the required moment resistance of the crank is maximum for balancing the mechanism. Upon moving the slider pin, the value of θ changes within the interval from 0 to π, which consequently adjusts both subplots on the right side, to accurately depict the visual representation of the mechanism and its state in the graphical plot. Thus, by embedding the previously shown "computations algorithm" as a module within an interactive App, MATLAB becomes not only a solver but also an interactive visualization and exploration environment. This real-time interactivity provides a deeper intuitive understanding of the physical behavior of the system, making the learning experience significantly more engaging than static diagram analysis.

4. RESULTS AND DISCUSSION

The computational analysis performed in MATLAB yielded a continuous and well-behaved resisting-moment function (θ) over the entire interval of angle $\theta \in [0, \pi]$. The numerical results, presented by the graphical plots of figure 2 and the right subplot of figure 3, confirm the nonlinear dependency between the crank angle and the resisting moment necessary to maintain equilibrium. The extrema of the function, corresponding to a specific mechanical

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configuration of the system, were automatically identified using the built-in peak and zero-crossing detection routines incorporated within the MATLAB script. These values represent configurations where the applied loads induce critical mechanical conditions, such as maximum tensile contribution from the cable or minimal stabilizing moment from the weight of the lever arm.

The graphical representation generated by MATLAB (Figure 2) provides immediate insight into how geometric configurations influence the resulting equilibrium moment. Regions where the slope of the curve is steep indicate high sensitivity to small changes in θ, whereas flatter regions correspond to quasi-stable configurations where the moment requirement remains relatively constant. Such interpretations are difficult to infer solely from analytical expressions, underscoring the added pedagogical value of computational visualization.

Expanding the methodology into the interactive MATLAB App (Figure 3) further enhances the analytical depth of the investigation. By allowing users to adjust masses, geometric parameters, and gravitational constants, the App offers a platform to explore system sensitivity and parameter dependence in real time. The ability to dynamically manipulate the crank angle θ provides immediate visual feedback on changes to both the geometric configuration of the mechanism and its associated resistance moment. This direct interactivity bridges the gap between theoretical statics concepts and their physical interpretation.

From an educational perspective, the integration of a responsive GUI allows students to engage in exploratory learning, where they independently investigate relationships between forces, geometry, and equilibrium conditions. Additionally, features such as automatic detection of critical angles, data export options, and real-time animation of the mechanism elevate MATLAB beyond a computational tool, positioning it as an experimental environment for learning and validating mechanical principles.

Overall, the results show that MATLAB—both as a coding environment and through the developed App—provides an accurate, efficient, and conceptually rich method for analyzing the resisting moment of crank-and-cable mechanisms. Thus, the MATLAB platform succeeds not only in reproducing manual analytical results but also in extending the analysis into domains impractical or cumbersome to explore manually.

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5. CONCLUSION

This study shows that MATLAB is not only capable but highly effective for analyzing statics problems in engineering mechanics. By automating the calculation of the resisting moment (θ), MATLAB removes the difficulty and potential errors that often accompany hand calculations—especially for systems where several forces interact simultaneously. Its numerical tools allow the moment to be evaluated quickly and accurately, and its plotting capabilities translate these results into clear visuals that make the underlying mechanical behavior much easier to interpret.

The creation of an interactive MATLAB App further enhances these benefits. With adjustable input parameters, a real-time θ-slider, and an instantly updating sketch of the mechanism, the App turns what is typically a theoretical exercise into a hands-on learning experience. Users can experiment with different geometric and physical parameters and immediately see how these changes affect the mechanism. Features such as automatic detection of maximum moments or equilibrium angles give learners powerful insight into how the system behaves.

From an educational perspective, this approach supports modern engineering teaching methods that emphasize visualization, experimentation, and computational proficiency. MATLAB's ability to seamlessly combine numerical analysis, graphical interpretation, and user interaction makes it more than just a calculation tool - it becomes an active component of the learning process. Integrating such tools into engineering courses can deepen students' conceptual understanding, improve their analytical accuracy, and help develop computational skills that are increasingly essential in today's engineering practice.

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ANALYSIS OF ERRORS MADE BY 7TH GRADE STUDENTS IN SOLVING FIRST-DEGREE EQUATIONS (CURRICULUM OF NORTH MACEDONIA)

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Abstract

The solving of first-degree equations is one of the most important parts of mathematical education during primary school. Despite its importance, students very often have difficulties in understanding and applying the basic rules for transforming and solving equations. The research described in this paper focuses on analyzing the most common mistakes made by seventh-grade students in North Macedonia, covering data from 150 students and 450 solved tasks. Moreover, the research classifies a number of factors that normally lead to those types of errors: poor concepts, inappropriate learning methodologies, and an absence of working out exercises. In the results it is reflected that the most errors have taken place due to inappropriate transformation between the equations that took 45%, and computation error took the second position having 35%. The remaining 20% were connected with problems involving word problem interpretation. This study also draws out striking differences in performance, related to student location, such as urban versus rural.

Keywords: First-degree equations, Mathematical education, Primary school mathematics, Student difficulties, Equation transformation errors

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1. Introduction

First-degree equations are the very basics of algebra and a critical point in one's mathematical education since it is through them that students start developing their reasoning and problem-solving skills. This concept teaches students how to manipulate mathematical expressions step by step in order to isolate and find the value of an unknown variable, which is essentially important not only for further study in mathematics but also for solving real-life problems. The application of first-degree equations runs from simple calculations to complicated scientific and technical analyses, further underlining their importance *(Smith, J., & Brown, K., 2018).*

First-degree equations are fundamental for developing students' mathematical skills and logical reasoning. They are essential not only for further mathematical studies but also for real-life applications. According to *Aliu et al.,* there is a significant correlation between additional activities such as homework, extra study hours, and student engagement with their success in mathematics *(Aliu et al., 2021).* Students who actively practice problem-solving and have access to additional support demonstrate better results and make fewer mistakes when solving equations. This highlights the need for effective teaching strategies that ensure conceptual understanding and procedural fluency in solving first-degree equations.

Despite the importance of mastering these equations, students often struggle due to conceptual gaps, inefficient teaching methods, and a lack of interactive learning tools. Research has shown that digital learning resources, such as GeoGebra, can significantly enhance students' understanding and retention of mathematical principles (*Mollakuqe et al., 2021*). According to *Mollakuqe et al.,* students who were taught mathematical properties using GeoGebra demonstrated higher accuracy in problem-solving compared to those who used traditional methods *(Mollakuqe et al., 2021).* Their study also highlighted that visualizing mathematical relationships in an interactive environment helps students grasp abstract concepts more effectively, particularly in topics involving geometric transformations and algebraic manipulations. Additionally, they found that the incorporation of dynamic software like GeoGebra led to increased student motivation and participation, as learners could experiment with different scenarios and instantly see the impact of their changes on mathematical models." According to *Kamberi* et al., practical illustrations have a significant impact on understanding and performing operations with fractions in sixth-grade students *(Kamberi et al. 2022).* They emphasize that using visual representations, such as images and video lessons, helps avoid common errors and improves students' ability to understand and apply operations with fractions.

Moreover, their study shows that practical illustrations have a greater effect compared to using programs like GeoGebra and Mathematica for solving tasks. This highlights the importance of practical illustrations in the process of learning mathematical concepts.

These findings suggest that combining practical illustrations with digital tools like GeoGebra can be an effective approach for improving students' understanding and application of mathematical concepts.

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First-degree equations are at the heart of developing mathematical competencies within the mathematics curriculum in 7th grade in North Macedonia. It is believed that students will develop competencies in mastering basic solution techniques for such equations and learn to contextualize those practices in different frames, such as solving problems using a word setting that needs translation from real life by using mathematical expressions.

Despite the importance and wide applicability of the topic, experience has shown that lots of students cannot master first-degree equations. The roots of such struggling may be a partial understanding of concepts, not enough practice of operations, or ineffective teaching practices. In view of this, this area really needs some innovation in methods and techniques of teaching to make learning effective and to build analytical skills for the learner.

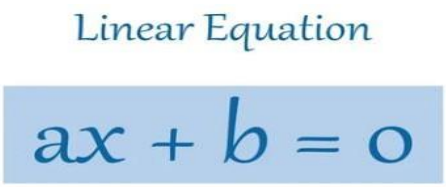

Figure 1. Illustration of Linear Equation

For example, consider the equation: $2x + 5 = 15$ The student is required to isolate the variable x by logically applying operations:

$$2x = 15 - 5 \implies 2x = 10 \implies x = \frac{10}{2} = 5$$

Although this procedure seems simple, data analysis shows that many students make mistakes at different steps of the solution. These errors may result from misunderstandings of concepts, incorrect memorization of rules, or a lack of practical application.

This research aims not only to identify the most common mistakes but also to provide insight into their causes and suggest strategies for improving instruction.

1.1 Methodology

The research employed a combination of quantitative and qualitative methods to ensure a comprehensive analysis of the research questions. Previous research has shown that visualization and practical examples play a crucial role in improving students' conceptual understanding (*Kamberi et al., 2022*). A diverse sample of students was selected from three primary schools located in different regions of North Macedonia, including urban, semi-urban, and rural areas. This

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approach aimed to capture a wide range of demographic characteristics. Teachers participating in the study were chosen based on their experience and dedication to the teaching profession.

1.1.1 Participants

The study involved students from various socio-economic backgrounds and geographic locations to provide a broad perspective on common errors in solving linear equations. A total of 450 tasks, consisting of tests and homework, were analyzed to determine the most frequent types of mistakes made by students. Additionally, 12 experienced teachers were interviewed to gain insights into their perspectives, experiences, and the challenges they face in teaching linear equations.

Figure 2. Participants

1.1.2 Data collection

Data collection was conducted through multiple sources to ensure a holistic understanding of the issue. The primary data sources included:

Task Analysis: Examination of 450 student assignments (tests and homework) to identify error patterns and their frequency.

Semi-Structured Interviews: Conducted with 12 teachers to explore their attitudes and experiences regarding common student errors and teaching strategies.

Classroom Observations: A total of 15 hours of classroom observation were carried out to analyze teacher-student interactions and instructional methods.

1.1.3 Data analysis

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The collected data were analyzed using SPSS software, applying various statistical methods to derive meaningful insights. Descriptive statistics were used to determine the frequency of errors, while correlation analyses were performed to explore the relationships between demographic factors (such as gender, type of school, and region) and student performance. This analytical approach provided valuable findings that contributed to the formulation of recommendations for improving teaching practices.

By integrating both quantitative and qualitative methods, the study aimed to provide actionable insights that can help educators address common challenges in teaching linear equations.

2 Understanding the first-degree equation

To solve a first-degree equation or inequality, it is possible to use various general methods (including the balancing equation method, the inverse operation method, the hidden term method, and trial-and-error). These methods are explained in the following concept sheet:

A **first-degree equation** is one that can be reduced to the form $0 = ax + b$

When we solve such an equation, we attempt to determine the value of the variable that makes the equation true. To do this, it is important to remember that to keep the equality in the equation, we must apply the same calculations to both sides of the equation *(Johnson, R., & Miller, T., 2015).*

Example:

What is the value of x in the equation below? $2x + 3 = 7$

1. To eliminate the term +3 from the left, we must subtract 3 from both sides of the equation

   $2x + 3 - 3 = 7 - 3$

   $2x = 4$

2. We try to find the value of a single x. To do this, we divide each side of the equality by 2.

$$\frac{2x}{2} = \frac{4}{2}$$

$$x = 2$$

Answer: The value of x *is* 2.

Example:

What is the value of x in the equation below?

$$\frac{2x}{3} - 16 = -6$$

1. To eliminate the term −16 from the left, we have to add 16 to both sides of the equation.

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$$\frac{2x}{3} - 16 + 16 = -6 + 16$$

$$\frac{2x}{3} = 10$$

2. We need to isolate the $2x$ .Thus, we must multiply both sides of the equation by 3.

$$\frac{2x}{3}3 = 10 * 3$$

$$2x = 30$$

3. To isolate the x, we divide both sides of the equation by 2.

$$\frac{2x}{2} = \frac{30}{2}$$

$$x = 15$$

The value of x is 15.

2.1.1 Results and Analysis

Table 1: Descriptive statistics for frequency on mistakes

Category	Medium value	Standard deviation	Minimum	Maximum
Errors in tests	12.3	3.2	7	20
Errors in domestic tasks	8.5	2.7	4	15
Total mistakes	20.8	5.1	12	30

Table 2: Results from correlational analysis

Variables	Coefficient on correlation (r)	P-value	Interpretation
Demographic factors and errors	-0.45	< 0.01	Negative correlation (significant)
Type school and success	0.60	< 0.01	Positive correlation (significant)

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Interventions on teachers and mistakes	-0.50	< 0.05	Negative correlation (significant)

The results from the research show that the most common mistakes made by students are related to three basic types: errors in transformation, computational errors, and problems with word problems. Transformation errors occur when students incorrectly move a term in the equation. For example, in the equation:

$$5x - 7 = 18$$

instead of the correct first step $5x = 18 + 7$,
they incorrectly decide on $5x = 18 - 7$, which leads to an incorrect solution. Computational mistakes occur when the equation is set up correctly, but the arithmetic is done incorrectly. For instance, in the equation

$4x + 8 = 28$, the number "8" is correctly moved, but the division is performed incorrectly:
$x = \frac{28}{4} = 7$

Problems with word problems most often arise from insufficient understanding of the text, leading to incorrect setup of the equation. For example, in a problem where a seller sold three T-shirts and one jacketfor a total of 2000 denars, and the jacket costs 1200 denars, the correct solution would be:

$$3x + 1200 = 2000 \Longrightarrow 3x = 800 \Longrightarrow x = \frac{800}{3}$$

However, students often set up the equation incorrectly.

The descriptive statistics indicated that the participants attempted to solve the linear equations, but most of those attempts did not provide the correct answers. That means the participants made some mistakes while solving the equations. Number line error was the most frequent error detected. According to *Hall*, one of the necessary skills in learning to solve simple linear equations is to be able to simplify expressions such as -3 + 1, involving understanding operations with integers *(Hall, 2002)*. In this study, the number line error was present in all equations on the test, but it appeared most frequently in equations 2 and 5. Figure 2 shows an example of the number line error made by a participant where the participant answered 2 for 3 - 5 when the correct answer should have been -2.

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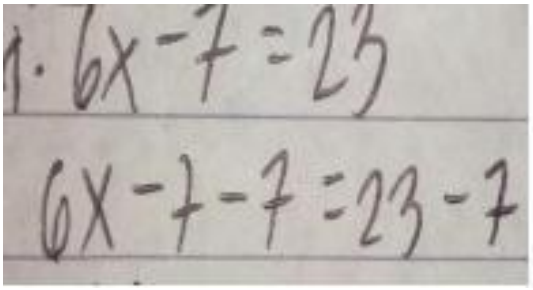

Figure 3

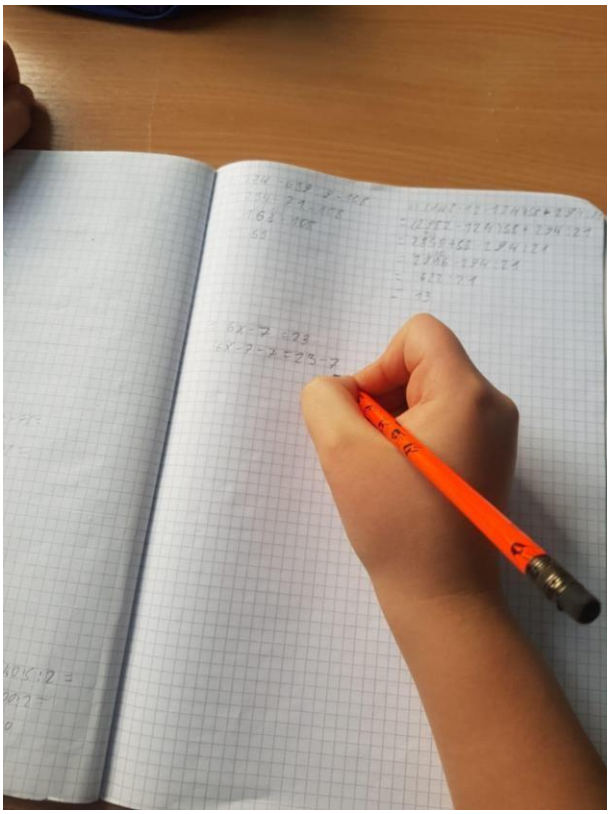

Figure 4

The next common mistake was the application of the additive inverse incorrectly, as well as that was mainly noted in equations 3 and 4. This according to *Hall* this kind of mistake should imply that a child understands the balance analogy since the same operation has been applied on both sides of the equation *(Hall, 2002).* However, in solving the equation by addition or subtraction of the opposite of a number on both sides, the participant found the wrong additive inverse. Figure 5 In this example, the participant actually subtracted 7 from both sides of the equation when in fact the additive inverse was 7 as the participant wanted to solve for X.

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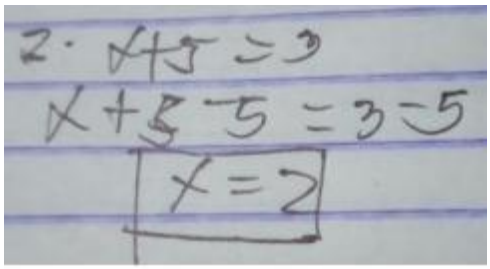

Figure 5

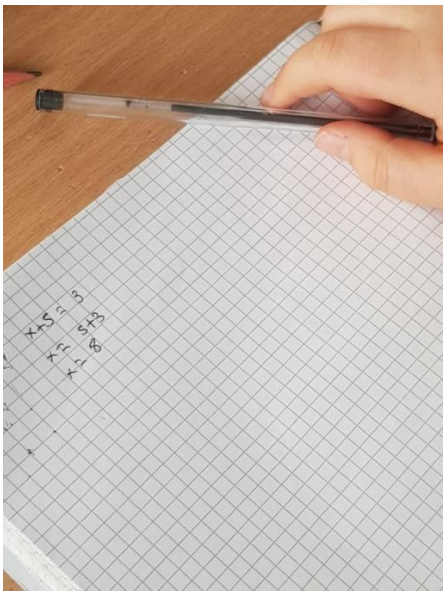

Figure 6

According to *Hall*, omission errors generally happen at the middle of the problem-solving process during the applying of a structural method *(Hall, 2002)*. The errors occur when a student missily leaves out some letters or numbers in presenting his solution for no apparent reason. The omission error occurred most in this study in equation 5. Figure 7 shows that the participant had correctly applied the property of equality, used the additive inverse, but then he accidentally omitted the variable x.

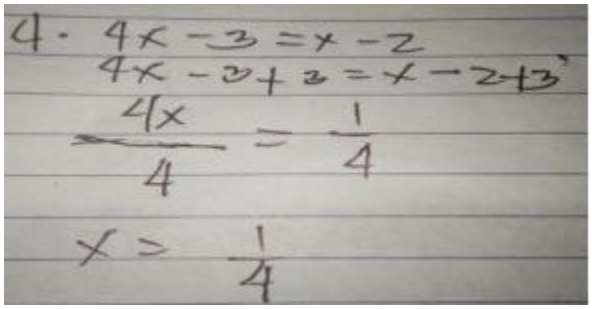

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Figure 7

Figure 8

It is likely that she omitted xxx without any clear reason as she struggled to manage the problem and attempted to simplify the equation. On the other hand, transposing errors were commonly found in equations 3 and 6 throughout this study.

Figure 9 illustrates an example of this error, where the participant incorrectly multiplied the denominator and the constant on the right side of the equation, resulting in $10 + x = 4$. According to *Hall*, transposing errors may arise when a student develops a problem-solving approach based on what seems to work frequently *(Hall, R., 2002)*. Conversely, the absence of structure error, as described by *Hall*, occurs when a participant fails to apply the same operation to both sides of the equation. Instances of this error in the study indicate that the pupil lacked a clear understanding of the principle of maintaining balance by performing equivalent operations on both sides *(Hall, R., 2002)*.

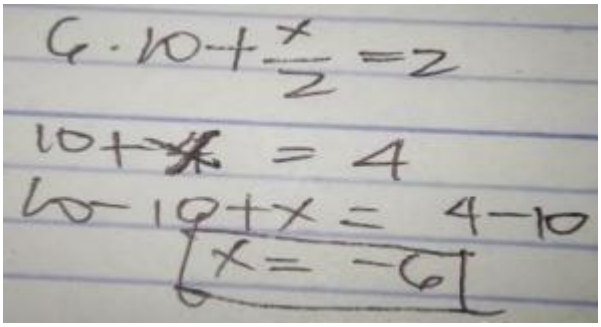

Figure 9

As shown in Figure 10, the participant subtracted 3 from the left side of the equation but failed to do the same on the right side. This suggests a possible lack of understanding of the

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property of equality. On the other hand, division errors were commonly observed in equation 1. While division errors may appear relatively minor in the context of solving linear equations, *Hall* notes that mastering division is crucial *(Hall, R., 2002)*. Without this skill, students who do not use calculators may struggle to find non-integer solutions to linear equations.

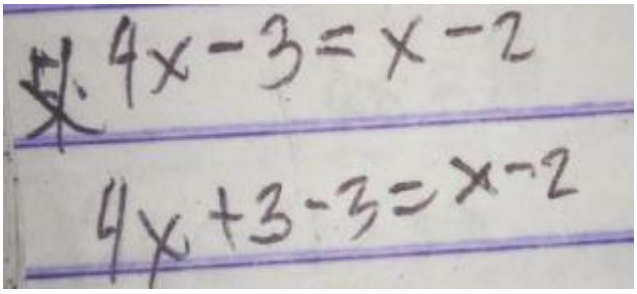

Figure 10

Figure 11 illustrates an error where the participant incorrectly calculated the quotient of 72 and 8 as 8. The second least frequent type of error observed was the switching addends error, in which an equation such as $x + 37 = 150$, is mistakenly interpreted as having the same solution as $x = 37 + 50$, 9. *(Kieran, C., 1992)*. In this study, this type of error was most commonly seen in equation.

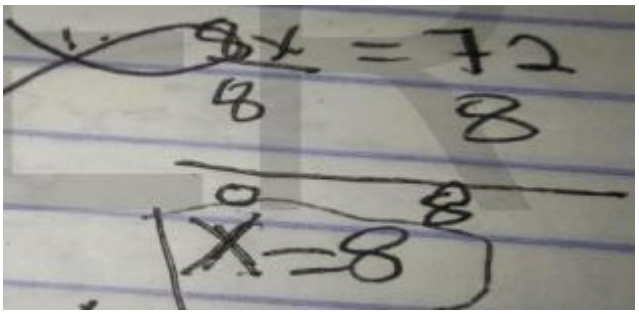

Figure 11

As depicted in Figure 12, the participant transferred 5 to the right side, incorrectly combining it with 3 to produce the result $x = 8$. The least frequent error identified in this study was the inability to isolate the variable.

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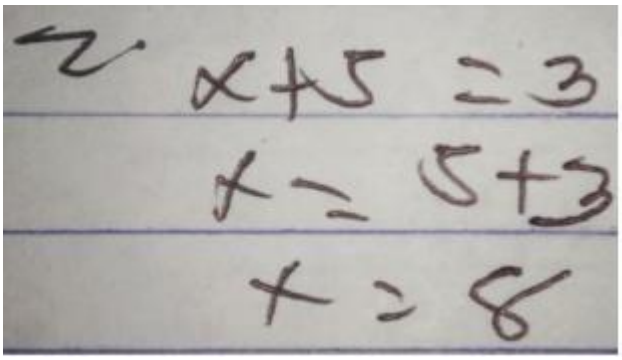

Figure 12

Figure 13 demonstrates that the participant was unsure of how to proceed after reaching the equation

$2x = 16$ through the cross-multiplication process. These findings indicate that teaching students to solve basic linear equations in one variable presents a significant challenge for educators.

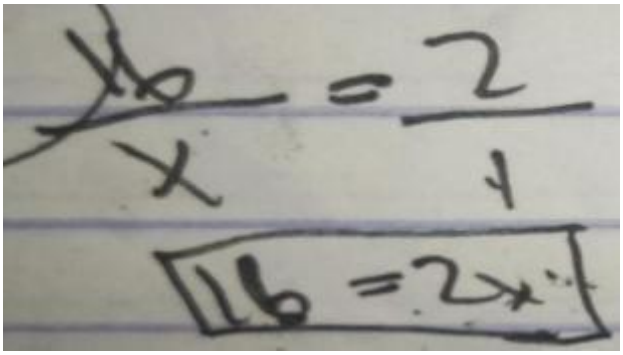

Figure 13

2.1.1 Statistical Data

Table 3: Frequency on mistakes

Type on mistake	**Percentage (%)**
Transformation on equations	20%
Computational mistakes	15%
Problems with textual tasks	65%

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2.1.2 Questionnaire

(For students, teachers, and observations)

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Section 1: Basic Information about Students

1. Which primary school do you attend?
    - Urban
    - Semi-urban
    - Rural
2. What is your gender?
    - Male
    - Female
3. Do you receive additional help with mathematics at home?
    - Yes
    - No
4. How often do you complete your math homework?
    - Always
    - Sometimes
    - Rarely

Section 2: Student Engagement in Class

5. When new material on equations is explained, how do you feel?
    - Very understandable
    - Partially understandable
    - Difficult to understand
6. Do you actively participate in class discussions?
    - Yes
    - No
7. What do you find most challenging when solving equations?
    - Understanding formulas
    - Calculation errors
    - Other (please specify): _____

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Section 3: Teacher Perspectives

8. How many years have you been teaching mathematics?
    - Less than 5 years
    - 5–10 years
    - More than 10 years
9. What types of errors do you most often notice among students when solving equations?
    - Errors in equation transformation
    - Incorrect application of operations
    - Misunderstanding of mathematical terms
10. What strategies do you use to help students avoid mistakes?
    - Providing more examples
    - Working individually with students
    - Using visual aids

Section 4: Observations

11. How is the teacher-student interaction during lessons?
    - Excellent
    - Good
    - Satisfactory
    - Unsatisfactory
12. How do students react to assigned tasks?
    - Confidently
    - Fearful of mistakes
    - Show no interest
13. Does the teacher use innovative methods to explain the topic?
    - Yes
    - Partially
    - No

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Section 5: General Recommendations

14. How can the teaching of mathematics regarding equations be improved?
    - o _____
15. Do you think additional activities, such as workshops or group exercises, would help?
    - o Yes
    - o No

Note: All responses will be treated as confidential and used solely for research purposes.

3 Recomandations

- **Incorporate Interactive Tools:** Utilize digital tools such as GeoGebra to help students visualize mathematical problems, enhancing their understanding and application of abstract concepts.
- **Use Real-World Applications:** Introduce word problems that relate mathematical concepts to everyday situations to increase student motivation and relevance of the material.
- **Provide Individualized Support:** Organize workshops tailored to students who struggle with specific topics, allowing teachers to address their unique challenges and foster progress.
- **Implement Self-Assessment Tests:** Offer short, periodic self-assessment quizzes to help students identify their weaknesses and monitor their improvement, promoting active engagement in their learning journey.

Based on these findings, the following strategies are recommended to mitigate errors in solving first-degree equations:

1. **Integrate GeoGebra into Classroom Instruction:** Use GeoGebra to provide students with a visual representation of equations and their transformations, minimizing conceptual errors (**Tuda & Rexhepi, 2024**).
2. **Enhance Traditional Methods with Interactive Learning:** Encourage the use of digital tools alongside classical teaching methodologies to reinforce student understanding (**Mollakuqe et al., 2021**).
3. **Implement Real-World Applications and Practical Illustrations:** Use financial scenarios, measurement-based tasks, and balance-scale analogies to strengthen conceptual understanding (**Kamberi et al., 2022**).

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4. **Encourage Structured Problem-Solving Techniques:** Train students in systematic approaches to mathematical problem-solving, ensuring they follow clear steps and avoid omission errors (**Aliu et al., 2023**).

4 Discussion and Strategies

One of the most effective ways to reduce student errors in solving first-degree equations is the integration of interactive digital tools like GeoGebra. Research by **Tuda & Rexhepi (2024)** demonstrates that GeoGebra significantly reduces conceptual misunderstandings by allowing students to visualize problem-solving steps, which in turn minimizes transformation errors. Applying this approach to linear equations could help students develop a more intuitive grasp of algebraic manipulations and reduce the frequency of errors related to equation transformation.

Additionally, **Mollakuqe et al. (2021)** compare the effectiveness of traditional teaching methods with GeoGebra-based instruction in teaching circle properties. Their findings suggest that students using GeoGebra perform better in problem comprehension and execution. These insights could be applied to teaching first-degree equations by using interactive visual aids that highlight the correct transformation process and reduce computational errors.

Practical illustrations have also been shown to positively impact student understanding. **Kamberi et al. (2022)** found that sixth-grade students better understood fractions when presented with real-world examples and visual models. Applying a similar method to first-degree equations—such as using balance scales or real-world financial scenarios—can provide students with tangible references for equation-solving principles, reducing the likelihood of errors.

A complementary approach is the use of structured problem-solving strategies. **Aliu et al. (2023)** emphasize that understanding mathematical problems through structured methodologies like Pascal's triangle improves students' analytical abilities. While Pascal's triangle is primarily used in combinatorics, its structured approach to problem-solving could be adapted to first-degree equations, helping students break down problems into systematic steps and avoid common mistakes.

5 Conclusion

Results reveal that students' equation-solving errors represent complex combinations of various influences in their poor learning environments characterized by ineffective instruction, less engagement with learning material, and weak concept comprehension. Traditional teaching methodologies support these deficiencies through the reduction in opportunities to develop problems as exercises with hands-on work in activity interaction. Moreover, without frequent and focused practice, the confidence in applying what is learned may fail, and the inability to contextualize problems will cause confusion in the interpretation and setting up of word problems.

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It would significantly improve the learning process by applying the strategies proposed herein, which include the integration of modern visualization tools, use of tasks that link mathematics to real-life situations, and provision of individual support. Introduction of interactive technologies like GeoGebra enables students to better visualize mathematical problems and understand their structure. In this, lie word problems applicable in real life that further motivate and attract students, necessary for long-term retention.

Additionally, creating an atmosphere where students believe they can make progress at their own pace in learning requires extra support: individual workshops and short self-assessment tests. The individual approaches help the students to get over their weaknesses and believe in themselves, while the self-assessment tests help them follow their progress and take responsibility for their learning.

This research underlines that efficient teaching methods, interactive technologies, and targeted support in overcoming the most common challenges students face when solving equations may be combined by teachers. Students will not only achieve better success with such an approach, but it will also foster a stronger interest and passion for mathematics as a foundation for future learning.

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THE INTERACTION BETWEEN MANAGEMENT AND LEADERSHIP IN CONTEMPORARY BUSINESS ORGANIZATIONS

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ABSTRACT

Market dynamics and the process of transformation of organizations nowadays are continuous processes so the interaction between management and leadership represents a key factor in business success and sustainability. Our study aims to analyze the relationship between the two concepts — management as a function of structure, planning, and control vs leadership as a process of influence, motivation, and inspiration of individuals toward organizational goals. Through a theoretical and comparative approach, the paper will examine the complementary roles these two functions play in the development of modern organizations, drawing on classical management theories (Fayol, Drucker) and contemporary models of transformational and situational leadership (Bass, Hersey & Blanchard). The analysis shows that organizations capable of integrating managerial skills with leadership competencies demonstrate higher efficiency, greater innovation, and a more sustainable organizational culture.

The study concludes that successful managers in contemporary business are not just administrators of resources but also a visionary leader who guides teams toward change and shared values. The balance between managerial structure and leadership influence remains a crucial factor for sustainable growth and competitiveness in the market.

KEYWORDS: Management, leadership, contemporary organization, motivation, efficiency, organizational culture.

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3 Introduction

Nowadays something that has been characterized by markets is rapid technological development, international competition and constant changes. These conditions are shaping business by increasing pressure on adapting and evolving. Because of this context the relationship between management and leadership has become one of the most discussed issues in organizational studies. Sometimes these two concepts are misunderstood in practice, but their theoretical foundations differ. Management focuses on structuring and implementation of processes, while Leadership is oriented in influence, inspiration, motivation and direction.

The interaction between management and leadership significantly influences organizational adaptability and performance this is proved by Mouazen et al. (2024 in a study of companies implementing Kotter's change-management model that leaders who combine transactional management-style and transformational leadership-style behaviors are more successful in driving sustainable change (Mouazen, Hernández-Lara, Abdallah, Ramadan, Chahine, Baydoun, & Bou Zakhem, 2024).

In the hospitality industry, Khairy, Baquero, and Al-Romeedy (2023) showed that transactional leadership boosts organizational agility through the mediation of trust highlighting how managerial control paired with relational leadership can help firms respond quickly to market changes.

At the same time, organizational culture matters: a study in Frontiers in Psychology revealed that managers' psychological well-being is linked to transformational leadership behaviors, particularly in rational or group cultures, which in turn supports both innovation and employee trust. These business cases suggest that successful organizations do not rely solely on rigid control systems; instead, they integrate structured managerial processes with leadership that inspires, motivates, and builds trust.

So, this paper aims to analyze these two dimensions, and how they complement each other in case of business organizations. Our approach is theoretical and comparative, relying on established root concepts in management theory and modern leadership. We would like to bring on focus the argument that long term organizational success requires an integrated approach where managerial structure supports leadership goals and on the other side leadership encourages managerial system.

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3.1 Theoretical Background

3.1.1 Management functions: structuring, planning and controlling

Fayol as classical author defined management through core functions as: planning, organizing, commanding, coordinating and controlling. Today these elements remain relevant but new authors are interpreting in more flexible and adaptive way. Drucker expanded his view of management by emphasizing effectiveness, not just efficiency as a key dimension in managerial work. Successful managers build clear goals, allocate resources wisely and ensure that the process is stable.

In modern or contemporary organizations, management includes monitoring performance and coordination by maintaining consistency in operations. Even if business is becoming more collaborative, the need for managerial discipline has been increasingly evident. It has become more closely linked to strategic priorities and decision making.

3.1.2 Leadership as influence and Motivation

Unlike management, leadership is built around influence and higher human motivation. Transformational leadership theory – BASS, highlights the leader's role in motivating and inspiring colleagues and followers, creating a stabile vision and promoting innovation. While Hersey and Blanchard suggest that effective leadership depends on adapting style to the needs of maturity of followers. As we know managers may rely on formal and strict authority while leaders rely more on interpersonal relationships, communication and building trust. Leadership focuses on creating and understanding, encouraging and creating a strong organizational culture. These elements are essential in environments where change is constant by making it hard for employees to adapt immediately by not wasting time and by being effective.

The traditional boundary between management and leadership has started to become more clear; effective organizations recognize that **management** must integrate closely with **leadership behaviors** to drive adaptability, innovation, and trust. Siyal (2023), noted that leadership and management are not mutually exclusive but rather complementary capabilities: while management ensures stability and coordination, leadership provides the vision and motivational energy that propel organizations forward (Siyal, 2023).

The connection between management and leadership is very important in hybrid and digital organizations, traditional control systems alone are not enough to handle fast-changing markets. Coolen (2025) found that managers who mix transactional control with transformational leadership get better results in hybrid work, because trust and focus on results replace strict supervision. These findings show that modern management should combine structured processes with leadership that supports and motivates teamwork.

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3.2 Complementarity between Management and Leadership

3.2.1 Areas of Intersection

Management and Leadership differ conceptually but they intersect in different ways. First of all, both are leading toward as root concepts, they are oriented in achieving organizational goals and both require a set of skills like communication, decision making, coordinating people and enhancing collaboration. A manager who lacks leadership skills may struggle to gain commitment, while a leader lacking managerial discipline may create vision without implementation. That's why many modern business organizations do not separate these two roles by expecting their managers to be able to lead and leaders to be aware of managerial processes.

3.2.2 Contribution of Management to Leadership

Leaders with strong interpersonal influence depend on managerial systems to bring their ideas to life so planning, budgeting, and structured work processes provide the foundation upon which leadership initiatives can be actualized. Without clear systems, charismatic or visionary leadership may lead to enthusiasm but not sustainable results, that's why managerial structure protects the business organization from chaos and ensures continuity.

3.2.3 Contribution of Leadership to Management

Leadership transmits energy, meaning, and direction to managerial work, it encourages teams to collaborate, creates motivation for change, and strengthens commitment to common goals. In rapidly changing markets, leadership has become indispensable for helping employees navigate uncertainty it also fosters creativity, which is crucial for organizational innovation. In this sense, leaders complement management by creating an environment where structured processes serve a dynamic, goal-oriented vision.

4 The Role of Integration of M&L in Contemporary Organizations

Integration of management and leadership as two sets of skills that complement each-other , now is widely recognized as a key factor for organizational development. Companies that rely solely on management tend to become rigid and slow to innovate, on the other hand, organizations led only through leadership inspiration but lacking managerial systems often face inconsistency and poor execution.

Aldhaheri and Ahmad (2022) demonstrated that transformational leadership significantly enhances organizational performance by improving knowledge-management capability. This

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integration enables companies to be more flexible: managerial processes maintain efficiency, while leadership ensures that knowledge flows across teams and aligns with strategy.

Moreover, the integration of leadership and management becomes particularly powerful when organizations face environmental turbulence, such as digital transformation or sustainability challenges. In a recent study in the manufacturing industry, researchers used Lewin's Change Model to show that transformational leaders drive resilience and agility, and when combined with structured managerial practices, this leads to long-term sustainability (Discover Sustainability, 2025).

By combining both competencies' organizations become enable to develop a culture of responsibility and adaptability. This balanced approach supports sustainable growth and ensuring operational stability while encouraging continuous improvement. Modern research in organizational theory suggests that hybrid managerial-leadership profiles are becoming the norm: professionals who can administer resources and inspire people at the same time (Soleymani & Ghavidast Kouhpayeh, 2024; Shi, 2024). But this integration becomes even more critical by the influence of digital transformation, so while digital tools support management processes with better data and automation, leadership is required to guide teams through technological change, manage resistance, and articulate the purpose behind innovation.

5 Conclusion

The empirical analysis presented in this paper shows that management and leadership, despite their conceptual differences, function most effectively when integrated. Management provides the structure and processes needed for organizational consistency, while leadership promotes engagement, vision, and readiness for change, so by managing a combination of both perspectives has demonstrated higher efficiency, stronger innovation capacity, and more sustainable organizational cultures.

Contemporary research shows that organizations that integrate both dimensions through hybrid managerial leadership profiles achieve better performance and sustainable growth, in digitally transformed and dynamic market environments (Soleymani & Ghavidast Kouhpayeh, 2024; Xie et al., 2025). Therefore, long-term organizational success depends on balancing managerial discipline with leadership influence, ultimately, the interplay of management and leadership is not a choice but a strategic necessity for organizations striving to thrive in an era defined by rapid change and technological development.

In contemporary business environments, successful managers are expected to go beyond administrative responsibilities, they are called to act as leaders who support collective values, encourage collaboration, and navigate change with clarity. The balance between managerial discipline and leadership influence remains an essential factor for long-term competitiveness and organizational resilience.

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SYSTEMIC CORRUPTION AND ORGANIZED CRIME IN NORTH MACEDONIA: INSTITUTIONAL WEAKNESSES, POLITICAL CONSTRAINTS, AND IMPLICATIONS FOR DEMOCRATIC DEVELOPMENT

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Abstract

Corruption and organized crime remain two of the most significant obstacles to democratic development, economic stability, and the rule of law in the Republic of North Macedonia. Although corruption is difficult to measure directly, numerous domestic and international indicators, ranging from public perception surveys to European Commission progress reports. consistently point to its widespread nature and systemic influence. Organized crime further deepens these challenges by infiltrating institutions, undermining governance, and contributing to security threats, including the financing of terrorist activities. This paper examines key findings from credible reports, including those of Transparency International, the U.S. State Department, the UN Office on Drugs and Crime, and the European Commission. Through a comprehensive analysis of these sources, the study highlights the erosion of institutional integrity, the lack of political will for reform, and the resulting decline in public trust. The findings underscore the urgent need for strengthened institutional capacity, transparent governance, and sustained political commitment to effectively combat corruption and organized crime.

Keywords: Corruption, organized crime, EU integration, political will, development

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Introduction

Corruption and organized crime pose profound challenges to the stability and development of modern states, particularly those undergoing transitional or post-conflict political processes. In the Republic of North Macedonia, these phenomena have long undermined democratic institutions, weakened the rule of law, and hindered progress toward European Union integration. Although corruption itself cannot be precisely measured, its effects are clearly visible across multiple sectors of society. Surveys consistently show that Macedonian citizens perceive corruption as the country's most serious societal problem, while trust in key judicial institutions remains critically low.

International assessments from Transparency International to the U.S. State Department and the Global Organized Crime Index continuously highlight persistent high-level corruption, political interference, and deep connections between powerful actors and criminal networks. Organized crime further threatens state security by exploiting institutional weaknesses, engaging in illicit financing activities, and fostering conditions for extremist and terrorist operations, particularly through drug trafficking.

European Commission progress reports from 2010 to 2020 reinforce these concerns, emphasizing chronic institutional inefficiencies, inadequate resources, and the absence of strong political will necessary for effective reform. These recurring observations reveal a structural pattern rather than isolated incidents, pointing to longstanding governance problems that continue to impede North Macedonia's development and its EU aspirations.

This paper provides a comprehensive analysis of these interconnected issues, drawing on the most credible national and international sources. By examining the state's vulnerabilities, the study aims to highlight the urgent need for systemic reforms, enhanced accountability, and a strategic approach to combating corruption and organized crime prerequisites for restoring public trust and achieving sustainable democratic progress.

This paper argues that the persistence of corruption and organized crime in North Macedonia is primarily the result of systemic institutional weaknesses and insufficient political will, and that meaningful progress toward democratic consolidation and EU integration requires comprehensive reforms that strengthen institutional capacity, enhance accountability, and dismantle entrenched political-criminal networks.

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The situation in the Republic of North Macedonia

"If corruption could be measured, it would probably be eliminated. In fact, conceptually it is not even clear what exactly one would want to measure!"[12] Measuring corruption is of crucial importance for effectively dealing with this phenomenon. However, this statement best describes the complexity of corruption when it comes to its measurement. There are several indirect indicators that can provide an idea of the extent of this occurrence within a country.

In the following, we will provide an analysis of credible reports, research, and other documents that we consider to offer sufficiently comprehensive information about the situation in the Republic of North Macedonia regarding corruption and organized crime.

The rule of law is one of the biggest problems faced not only by the Republic of North Macedonia but also by other countries in the region. Organized crime and corruption are often used in a shared context. Namely, the reason is simple: organized crime uses corruptive practices such as bribery, influence, etc., to infiltrate state institutions as well as other segments of society. If nothing is undertaken to address organized crime and the high rate of corruption, their direct impact on the economic and social stability of the state becomes evident.

In a study published by Transparency International on the impact of corruption and its erosive effects on the economy, several negative outcomes resulting from corruption are presented: the disruption of market forces through the misallocation of resources, and the diversion of talent and resources by engaging human resources in unproductive activities.[13] Organized crime and corruption contribute to economic stagnation and hinder sustainable development. Illicit financial flows stemming from money laundering and embezzlement divert resources away from legitimate economic activities. This economic outflow worsens poverty and inequality, obstructing overall growth and prosperity in states.[14]

Regarding the successful or unsuccessful handling of corruption, the latest reports by Transparency International on the Corruption Perceptions Index testify to this. According to these reports, the Republic of North Macedonia, with consistently poor results, is ranked the lowest among the countries in the region.[15]

According to the 2023 corruption assessment report for the Republic of North Macedonia, conducted by the Macedonian Center for International Cooperation (MCIC)[16], citizens perceive

[12] Tanzi (1998),pg. 576
[13] Anti-Corruption Helpdesk:The impact of corruption on growth and inequality, https://www.transparency.org/files/content/corruptionqas/Impact_of_corruption_on_growth_and_inequality_2014.pdf [accessed on 20.6.2020]
[14] United Nations Office on Drugs and Crime. (2017). "Economic and Social Consequences of Drug Abuse and Illicit Trafficking." Достапно на https://www.unodc.org/unodc/en/drug-prevention-and-treatment/economic- and-social-consequences.html [accessed on 20.6.2020.]
[15] Ранк листа достапна на https://www.transparency.org/en/cpi/2020/index/nzl [accessed on 20.6.2020] [16]Извештај за процена на корупцијата во Северна Македонија https://mcms.mk/images/docs/2023/MCMS_nacionalen_izvestaj_2023.pdf

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corruption as the biggest societal problem. Specifically, as many as 63.5% of respondents ranked corruption as the most serious issue among the 11 offered options. According to the same report, for more than 80% of Macedonian citizens, the leading factors influencing the spread of corruption in North Macedonia are the moral crisis in society and the inefficiency of the judicial system in combating corruption.

Another study on citizens' trust in institutions shows that the public trusts the judiciary the least (3.2%), followed by the Public Prosecutor's Office, which received 3.4% trust.[17]

The high rate and widespread nature of corruption are also confirmed in reports from the U.S. State Department (for 2020[18], 2021[19], 2022[20], and 2023[21]), which consistently repeat the same findings regarding high-level corruption and cases of serious government corruption. What is even more concerning, however, is the impact of organized crime on state security. Most commonly, organized crime finances the activities of terrorist groups. Financial resources crucial for recruitment, training, and maintenance of terrorist groups and their members often lead to cooperation with organized criminal networks, especially in the area of illicit drug trafficking. Money originating from illegal drug trade remains the *main source of income* for terrorist organizations.

Research conducted by the UN Office on Drugs and Crime (UNODC) shows that 80% of the world's opium and heroin production originates from Afghanistan. Following the Taliban takeover of Afghanistan in 2021,[22] the trend in opium production increased drastically, with an 8% rise recorded compared to the previous year.

One of the consequences of organized crime on the state is the damage it causes to the quality of its governance and rule. By undermining the integrity of public officials and institutions through corruption and intimidation, organized crime weakens the state in two key areas:

1. its capacity to deliver basic public goods and civil rights, and
2. its legitimacy as a political entity responsible for governance.[23]

[17] Речица, Влора. 2022. Јавната перцепција за довербата во политичките партии, јавните институции и квалитетот на животот во Република Северна Македонија. Анализа на јавното мислење, Скопје: IDSCS
[18] 2020 Country Reports on Human Rights Practices: North Macedonia https://www.state.gov/reports/2020-country-reports-on-human-rights-practices/north-macedonia/
[19] 2021 Country Reports on Human Rights Practices: North Macedonia https://www.state.gov/reports/2021-country-reports-on-human-rights-practices/north-macedonia/
[20] 2022 Country Reports on Human Rights Practices: North Macedonia https://www.state.gov/reports/2022-country-reports-on-human-rights-practices/north-macedonia/
[21] 2023 Country Reports on Human Rights Practices: North Macedonia https://www.state.gov/reports/2023-country-reports-on-human-rights-practices/north-macedonia/
[22] United Nations Office on Drugs and Crime, Drug situation in Afghanistan (2021) https://www.unodc.org/documents/data-and-analysis/Afghanistan/Afghanistan_brief_Nov_2021.pdf [accessed on 2.9.2022]
[23] Miraglia/Ochoa/Briscoe (2012), 13 pg

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In states with a low level of rule of law, particularly in post-conflict countries, organized crime operates more effectively due to the chaos and conditions that emerge within such states.

Organized crime and corruption have especially negative effects on citizens' trust in institutions, particularly in the institutions of the judiciary. According to a survey conducted by the Institute for Democracy[24], in our country, when it comes to trust in institutions, citizens trust the judiciary the least, with the lowest level of trust at 3.2%. The Public Prosecutor's Office also shows low trust, at 3.4%. Low public trust in judicial institutions may stem from several reasons, including the failure to resolve high-profile cases of organized crime and corruption, as well as the prolonging or expiration of cases involving individuals holding positions in the executive branch.

According to the Global Organized Crime Index, in the Republic of North Macedonia there is significant connectedness between people in power and criminal groups, and it appears that there is a certain degree of criminal capture of state institutions and influential political figures.[25]

In the annual reports of the European Commission, the country's progress in meeting the conditions for integration into the European Union is assessed. Beginning in 2005, when the Republic of North Macedonia obtained candidate-country status for EU membership, the European Commission has prepared progress assessment reports for each subsequent year. For this reason, the reports concerning the rule of law and fundamental rights for the period 2010–2020 will be analyzed below. This period is marked by many controversial political and legal situations that reflect the actual state in which our country has found itself.

Regarding the European Commission's reports on the progress of North Macedonia, one can observe repeated remarks about the weak capacity of institutions in dealing with organized crime and corruption. In almost all reports, it is noted that the institutions responsible for combating organized crime and corruption face a lack of sufficient financial resources, personnel, and other necessary elements required for a more effective and serious fight against crime.

The absence of these elements indicates that, so far, governments in the country have lacked genuine political will to combat organized crime and corruption, committing to this fight only rhetorically rather than through concrete and consistent action.

Conclusion

The collected analyses and reports consistently demonstrate that corruption and organized crime represent some of the most persistent and damaging challenges for the Republic of North Macedonia. Although corruption is a complex phenomenon that cannot be measured directly, numerous credible indicators including public perception surveys, international assessments, and

[24] Извештај од фокус-групи: Јавната перцепција за довербата во политичките партии, јавните институции и квалитетот на животот во Република Северна Македонија, Анализа на јавното мислење, бр.22/2022, октомври: https://idscs.org.mk/wp-content/uploads/2022/12/Izveshtaj-za-fokus-grupi-MKD.pdf
[25] Global organized crime index (2021), Global initiative against transnational organized crime https://ocindex.net/country/north_macedonia

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institutional reports reveal its deep entrenchment in the country's political, economic, and judicial systems. Citizens overwhelmingly recognize corruption as the most serious societal problem, with extremely low levels of trust placed in the judiciary and prosecution. This declining trust is largely driven by unresolved high-profile cases, political interference, and systemic inefficiencies within justice institutions.

Organized crime further exacerbates these weaknesses by undermining governance, infiltrating state structures, and creating fertile ground for intimidation, bribery, and institutional capture. International sources, such as the U.S. State Department and the Global Organized Crime Index, highlight substantial connections between political actors and criminal networks, suggesting patterns of state capture and sustained high-level corruption. Beyond undermining the rule of law, organized crime also poses serious security threats, particularly through its financial ties to terrorist groups and its role in the global drug trade.

European Commission progress reports reaffirm these internal and external assessments, repeatedly citing inadequate institutional capacity, insufficient resources, and the absence of genuine political will to address corruption and organized crime. Despite more than a decade of monitoring and recommendations, reforms have often been superficial, inconsistent, or hindered by entrenched interests.

Taken together, the evidence indicates that corruption and organized crime in North Macedonia are not isolated problems but deeply systemic issues that inhibit state functionality, weaken democracy, restrict economic development, and threaten national security. Meaningful progress requires sustained political commitment, stronger institutional independence, greater transparency, and comprehensive reforms aimed at restoring public trust and aligning the country with European democratic standards. Without these changes, the state risks continued stagnation and further erosion of public confidence in its core institutions.

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WHAT DRIVES MIGRATION IN NORTH MACEDONIA? EVIDENCE FROM THE LIFE IN TRANSITION SURVEY IV

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Abstract

Why are some individuals more willing to emigrate than others? What determines actual migration patterns in North Macedonia? Migration is one of the most important and complex challenges policymakers have to address globally, both in countries of origin as well as destination countries. In this paper we analyze a pressing issue for North Macedonia, namely, the main factors that contribute to migration and the intention to migrate. Using data from the nationally representative fourth round of the Life in Transition Survey we provide evidence about the most prevalent factors affecting the propensity to migrate. We consider economic and political factors, socio-demographic factors, psychological as well as personal values and attitudes regarding religiosity, democracy, environment and (dis)trust in institutions in shaping the intention to migrate. Using both descriptive and a logistic regression framework we assess the relative importance of these factors. The findings of this study contribute to the general policy debate on how best to tackle emigration, and the brain drain it entails. We highlight and discuss the most important factors to consider when designing policy interventions.

Keywords: Migration, survey data, migration drivers, intention to migrate, Life in Transition Survey

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1. Introduction

North Macedonia, like many Western Balkan countries, has a long history of migration with emigration rates accelerating during the past two decade. The country does not have its own statistics on migration stock or flows. The reason is that only a small portion of citizens report their temporary or permanent residence abroad. Therefore, the database of the Ministry of Interior and the State Statistical Office underestimate the population of citizens who have emigrated abroad. Migration data for North Macedonia is available only from national population censuses. The most recent 2021 Population Census which allowed individuals living abroad for more than a year to register, showed a non-resident population of 260,606 out of a total population of 2.1 million. Due to self-registration this number may underestimate the actual number of non-residents, nevertheless, it gives an indication that at least 10% of the population lives abroad. Foreign sources of information such as United Nations, World Bank, Eurostat etc. provide valuable and more realistic data on the extent and nature of migration in North Macedonia. According to Atlas of Migration 2020 (European Commission, 2020) the number of first residence permits issued to citizens of North Macedonia in receiving countries, within a year, was 24,040 in 2018 and 26,718 in 2019. Considering that some of the residents might have left with Bulgarian passports these numbers again may underestimate the actual migration abroad. In terms of migration stock data originating from North Macedonia, the total number of citizens living abroad reached 693,900 in 2020, almost one-third of the population. From 2008 emigration from North Macedonia accelerated due to visa-free entry of its citizens to EU member states in the Schengen area as well as the process of EU enlargement with Eastern European countries. Even though lack of complete data make it difficult to realistically determine the extent of migration in North Macedonia, World Migration Report 2020 puts North Macedonia's migration rate at about 25% placing the country among the top 10 according to this measure (International Organization for Migration, 2022; European Training Foundation, 2021).

Against this background, survey data addressing the issue of migration, become a valuable tool not only for assessing the extent of migration but also for giving a more nuanced view of different aspects of migration which cannot be obtained from standard official data. In this paper we use the most recent fourth round of the Life in Transition Survey IV (LiTS IV) conducted by the European Bank for Reconstruction and Development and the World Bank to analyze different aspects of migration in North Macedonia and to model the intention to migrate. The literature on determinants, consequences and the nature of migration in North Macedonia and wider (Li & Gade, 2023; Hagen-Zanker, Carling, Caso, & Rubio, 2025; Dennison, 2022; Barisic, Ghodsi, Sabouniha, & Stehrer, 2024; Migali & Scipioni, 2019; Kang, Kim, Hong, & Ko, 2020) highlights several factors as potential determinants of migration and

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the intention to migrate. Our goal is to test whether these factors are significant determinants in shaping the intention to migrate in North Macedonia. To this end we use a nationally-representative household-level database for North Macedonia – Life in Transition Survey - to construct several variables and build the model which will be described in more detail in the following sections.

6 Data and methodology

6.1 Data

The Life in Transition Survey (LiTS) is a household survey carried out by the European Bank for Reconstruction and Development (EBRD) and the World Bank (Ipsos, 2023). The purpose of the survey is to understand the effects of political and economic changes on the lives of people who live through them. The survey was initially conducted in 2006 in the former Communist block and Turkey, and subsequently in 2010, 2016 and the most recent fourth round in 2022. The fourth wave of the survey covered 33 countries in which the EBRD operates as well as 4 comparator economies making it the most ambitious in scale to date.

The survey population is defined as adults aged 18 years and above who live in private households and have lived in the selected household for at least six months. In each country, at least 1,000 households were interviewed. The primary survey respondent was selected randomly among all eligible household members. A multi-stage clustered sample design was used with primary sampling units (PSUs) selected at the first stage and addresses selected via random walk at the second stage. After the second stage, another stage of selection was implemented – an individual was randomly selected among all individuals eligible for the survey at the address. When selecting the PSUs (Polling station territories provided by the State Election Commission of Macedonia) the aim was to arrive at a balanced selection so that the sample proportions of the key variables match the population proportions on these variables. Region and urbanity were used to stratify the samples. Within PSUs addresses were selected randomly through the application of the random walk procedure, starting from a randomly selected address and selecting every nth address on the walk. The main respondent, then, was randomly selected among all eligible household members who were listed in the Electronic Contact Sheet (ECS) which is programmed to make a random selection.

The survey includes eight modules covering different topics from general demographic information such as gender, age, native language, religion, level of education, dwelling and assets, employment, attitudes and values, digitalization, etc. For the current analysis we focus on North Macedonia where 1002 interviews were conducted in total.

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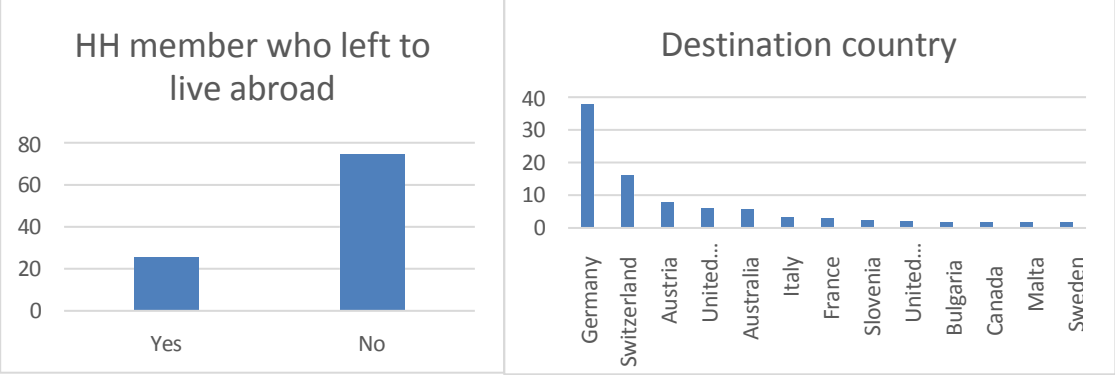
6.2 Stylized facts

Using the richness of the survey data, it is valuable to gain more insights into the demographic profile of individuals that have already left the household to live abroad. To this end we analyze responses to questions dealing with household members who have left the household to live abroad for at least 3 months, with regards to their age, gender, level of education, reasons for leaving, time spent away, whether they have since returned and whether they are seasonal migrants.

As shown in Figure 1, out of 1002 respondents, 256 or 25.5% have at least one household member who have left to live abroad, which is consistent with the United Nations World Migration Report 2020 which puts North Macedonia's migration rate at about 25%. In terms of the destination countries these individuals emigrate to, Germany, Switzerland, Austria, United States and Australia are the top five destination countries, followed by Italy, France, Slovenia, United Kingdom, Bulgaria, Canada, Malta and Sweden. With regards of the age of individuals who have left the household to live abroad, the mean age is 40 years, ranging from 20 to 76 years old. The age distribution is roughly normal with a median of 40 years old, skewness of 0.3 and a kurtosis of 2.7. Males constitute the majority of individuals who have left the country – about 75%. In terms of the education level of emigrants, the majority are with secondary education (about 58%), followed by a Bachelor's Degree (23%) and Master's or PhD (about 6%). The survey also asked respondents about the reasons the household member decided to leave. The top three cited reasons are to take a job (41.4%), to search for work (23.4%) and marriage/family reunion (18.7%). Other reasons include to provide financial support to family here, better education for children and to study abroad. With regards to the time the household member who left spent away, about 30% spent more than 10 years abroad, about 20% spent 6 to 10 years abroad and another 20% spent 2 to 5 years abroad. So in general, migration in North Macedonia is long-term rather than temporary/seasonal. This is confirmed with the next question which asked respondents: Is the household member who left a seasonal migrant?. About 91% answered *No* to this question.



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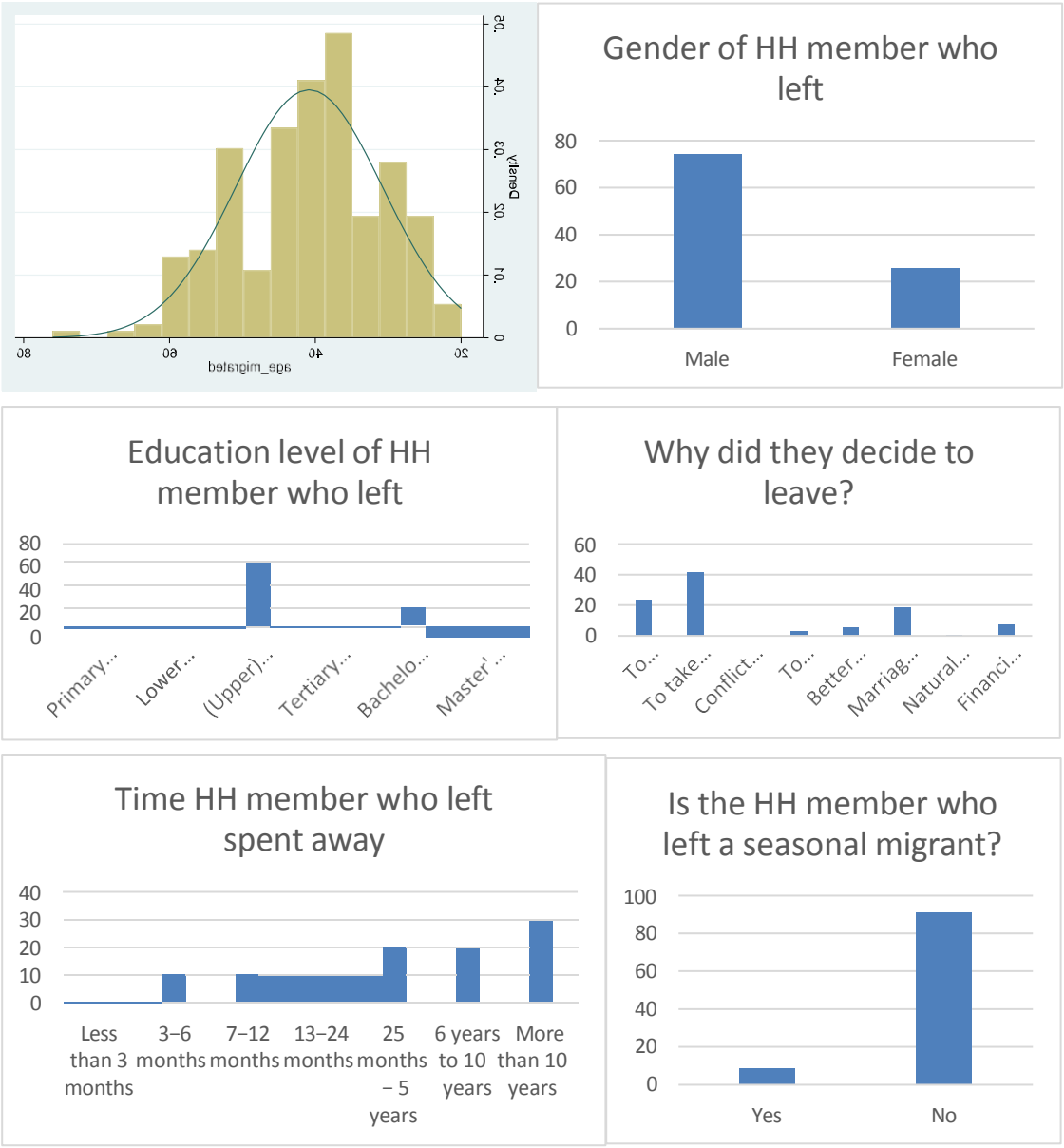

Figure 1: Characteristics of individuals who have left the household to live abroad

6.3 Variables and summary statistics

In this section we describe our main variables and their summary statistics. The definition of all the variables is given in the Appendix, whereas the summary statistics and the correlation matrix tables are given in Table 1 and Table 2, respectively. As we wish to determine what drives the intention to migrate we start by constructing the dependent variable Intention to migrate as a dummy variable which equals one if the respondent answered affirmatively to the question: Do you intent to move abroad in the next 12 months?, and zero otherwise. As can be seen from Table 1, about 10.2 percent of respondents answered affirmatively.

To understand the demographics of individuals with an intention to migrate we include

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variables such as gender, age, marital status and level of education. From a total of 1002 respondents in our sample, 42.4% are male, 62.4% are married, the mean age is 52 years (ranging from 18 to 89 years old) with the average education level being 4.3 (meaning secondary education).

We also include personality traits such as the willingness to take risks, which the literature has found to significantly impact migration patterns in different countries. This variable (Take risks) takes values from 1 (not willing to take risks at all) to 10 (very much willing to take risks). The average respondent in our sample has a risk taking propensity of 4, with a standard deviation of 2.7.

Another factor we consider is the experience of the household with prior migration. To this end we use the question: Does this household have any current or former member who left the household to live abroad for at least 3 months?, to construct the variable Experience migration as a dummy variable taking the value of one if the answer to this question is yes, and zero otherwise. About 25.5% of respondents answered affirmatively to this question.

Economic wellbeing, as another important factor when analyzing the intention to migrate is captured through the variables Live better and Afford holiday. We construct the variable Afford holiday using the question: In general, could your household afford the following if it wanted to: Each year, a one-week holiday out of home, including stay in second home, country house or at friends or relatives. The variable equals one if the answer to this question is affirmative, and zero otherwise. About 56% of respondents answered affirmatively to this question. The variable Live better is defined as a Likert scale variable taking values from 1 – Strongly disagree to 5 – Strongly agree in response to the following statement: My household lives better nowadays than around 4 years ago. The sample average of this variable is 2.5 with a standard deviation of 1.1.

Finally, we consider political factors and the level of trust in institutions as potential factors in shaping migration intentions of individuals. To measure the level of trust in institutions we build an aggregate indicator using the question: To what extent do you trust each of the following institutions: the presidency, the government, regional government, local government, the parliament, courts, political parties, armed forces, the police, banks, foreign investors, religious institutions, universities and public health authorities. The answers vary from 1 – Complete distrust to 5 – Complete trust for each of the institutions mentioned above. We construct an aggregate variable, Trust institutions as a sum of individual Likert scale variables. The aggregate variable, constructed in this way takes values between 6 and 70 with a sample average of 33. To measure political factors (Political instability) we use the question: I am concerned about political instability affecting North Macedonia in the next year. The answers range from 1 – Strongly disagree to 5 – Strongly agree. The sample average is 3.9 with a standard deviation of 1.04.

Table 2 shows pairwise correlation coefficients between all the variables used in the regression analysis. As shown in the table, the highest pairwise correlation coefficient is

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0.38 which suggests that there are no multicollinearity problems among the variables included in our model.

Table 1: Summary statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
Intention to migrate	1,002	0.102	0.303	0	1
Take riks	999	4.010	2.783	1	10
Male	1,002	0.424	0.494	0	1
Education	1,002	4.375	1.590	1	8
Age	1,002	52.307	16.824	18	89
Married	1,001	0.624	0.485	0	1
Afford holiday	997	0.560	0.497	0	1
Experience migration	1,002	0.255	0.436	0	1
Trust institutions	997	33.040	11.664	6	70
Live better	989	2.562	1.161	1	5
Political instability	961	3.908	1.040	1	5

This table shows summary statistics of the variables used in the analyses, number of observations (Obs), Mean value, Standard deviation (Std.dev.), minimum and maximum values. The definition of all variables is given in the Appendix.

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Table 2: Correlation matrix.

	1	2	3	4	5	6	7	8	9	1
1. Intention to migrate	1									
2. Take riks	0.2032*	1								
3. Male	0.0650*	0.1098*	1							
4. Education	0.1261*	0.2577*	0.0261	1						
5. Age	-0.2503*	-0.3791*	0.0077	-0.3125*	1					
6. Married	-0.0251	-0.0274	0.1430*	0.0469	-0.053	1				
7. Afford holiday	0.0328	0.2539*	0.0565	0.3791*	-0.3264*	0.1430*	1			
8. Experience migration	0.1282*	-0.1168*	-0.0583	-0.0764*	0.0980*	0.0811*	-0.0286	1		
9. Trust institutions	-0.0162	0.1438*	0.0174	0.0877*	-0.0436	-0.0511	0.1136*	-0.1346*	1	
10. Live better	-0.0193	0.1995*	0.0640*	0.1375*	-0.2246*	0.0809*	0.2814*	0.0124	0.2584*	1
11. Political instability	0.0032	-0.1014*	0.0142	-0.0114	0.1315*	0.0362	-0.0583	0.0745*	-0.0315	-0.10

This table shows pairwise correlation coefficients for all the variables used in the analysis. * denotes significance at 5% significance level.

6.4 Methodology

To assess the main factors driving the intention to migrate we use a logistic regression as our dependent variable is binary. With a logistic regression we model how the probability of success varies with the independent variables and determine whether or not these changes are statistically significant. In fact, we are modelling the logarithm of the odds. The logistic regression model takes the following form:

$$\log(odds(success)) = logit(\pi) = \log\left(\frac{\pi}{1-\pi}\right) = Q_0 + Q_1 demograph + Q_2 personality_i + Q_3 experience\ migration_i + Q_4 economic_i +$$

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$$Q_5 institutional_i + Q_6 political_i + \boldsymbol{\varepsilon} \quad (1)$$

where, $\pi(0 \leq \pi \leq 1)$ is the probability of an event happening (success), $\pi = P(success) = P(intention\ to\ migrate)$. Parameters Q_i are estimated using the maximum likelihood method. A positive (negative) and significant coefficient means that a one-unit increase in the predictor increases (decreases) the log odds of the outcome by Q_i.

3 Results

Table 3 presents the results of the logistic regression estimations. We can see from the results that all demographic factors (except the marital status) significantly impact the log odds of a positive intention to migrate. Being male, more educated and younger significantly increases the log odds of a positive intention to migrate. In addition, we have included a squared term for age, to investigate if the relation between age and the log odds of migration is linear or quadratic. We find a positive and significant coefficient for the age variable and a negative and significant coefficient for the age^2 variable. This means that the relation between age and the log odds of migrating is positive up to a certain point, and it turns negative beyond that point. More precisely, using the expression $\beta_{age}/2 * \beta_{age\hat{}2}$ we find that the turning point happens at 32 years of age. This confirms the results from the stylized facts that migration in North Macedonia is prevalent mainly among young and male individuals with higher education levels.

Personality traits such as the willingness to take risks significantly increases the log odds of migrating. We find a positive and significant coefficient at 1% significance level. Another factor which resulted positive significant at 1% level is the experience with prior migration. Individuals coming from households which already have a current or former member who left the household to live abroad are more likely to intent to migrate, meaning that migration entails more migration.

Variables which capture the economic wellbeing of individuals *Live better* and *Afford holiday*, both result negative and significant at the 5% significance level. The higher the economic wellbeing of individuals the less likely they are to intent to migrate, all other things being equal. It is important to emphasize here that having a job per se, i.e. being employed does not enter as a significant predictor of the intention to migrate. What is more important in shaping the intention to migrate is not just having a job, but the factors that contribute to the economic wellbeing of individuals such as how much they get paid, what can they afford with their income, the working conditions as well as the general standard of living that prevails in their household.

Finally, factors that measure the level of trust in institutions and how concerned individuals are about political instability in the country do not seem to be significant determinants of the intention to migrate. Their coefficients enter the regression with the expected signs, positive for the level of trust and negative for political instability, however they are not statistically significant at the usual significance levels.

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Table 3: Logistic regression results.

Intention to migrate	Coefficient	Std. err.	z	P>z	[95% conf.	interval]
Take risk	0.161	0.045	3.59	0	0.073	0.249
Male	0.573	0.244	2.35	0.019	0.096	1.050
Education	0.153	0.080	1.91	0.056	-0.004	0.309
Age	0.164	0.068	2.43	0.015	0.032	0.297
Age square	-0.003	0.001	-3.31	0.001	-0.004	-0.001
Married	-0.314	0.266	-1.18	0.237	-0.836	0.207
Afford holiday	-0.611	0.283	-2.16	0.031	-1.165	-0.057
Experience migration	1.523	0.263	5.8	0	1.008	2.037
Trust institutions	-0.004	0.011	-0.39	0.693	-0.025	0.017
Live better	-0.253	0.111	-2.28	0.023	-0.471	-0.036
Political instability	0.108	0.115	0.94	0.348	-0.117	0.332
Constant	-5.149	1.552	-3.32	0.001	-8.191	-2.107

This table shows the logistic regression results from estimating specification 1. The definition of all the variables is given in the Appendix.

4 Conluding remarks

In this paper we analyze migration patterns in North Macedonia using the household-level survey database – Life in Transition Survey IV. The richness of the database allows us to investigate different aspects of migration and to gain deeper insights into this issue, which cannot be obtained from standard official data. The initial analyses show that the migration rate in North Macedonia stands at 25% of the population, which puts North Macedonia at the top 10 countries worldwide according to this metrics. With regards to the demographics of individuals that have left the country to live abroad, the average emigrant from North Macedonia is male, 40 years old, with a level of education above secondary school.

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Furthermore, emigration in North Macedonia is long-term rather than seasonal and tends to be driven by employment opportunities abroad (to take up a job or search for work).

The logistic regression, which models the log odds of the intention to migrate as a function of demographic factors, personality traits, experience with prior migration as well as economic, institutional and political factors, reveals several interesting results. Demographic factors such as age, gender and the level of education are significant determinants of the log odds of a positive intention to migrate, as are the willingness to take risks and experience with prior migration. Among economic, institutional and political factors, only economic factors resulted statistically significant whereas political and institutional factors do not seem to play an important role in shaping the intention to migrate.

In alternative specifications (available upon request), we consider additional factors such as the ethnicity of the respondents - Albanian vs. Macedonian, religiosity – how important they consider religion to be in their life, psychological factors – whether the respondent is feeling anxious, sad, depressed, environmental factors – how concerned respondents are about air pollution, waste management, biodiversity, diseases, natural disasters, etc, as well as attitudes towards immigrants – whether they see them as a burden or a valuable contribution to the society. None of these factors resulted as statistically significant in the model.

We conclude that emigration in North Macedonia remains ultimately an economic phenomenon. Policies that ensure employment opportunities of young, educated people should be the priority. However, it is not employment in itself that matters, it is the working conditions, wages and increasing the overall standard of living and economic wellbeing that matters the most. In addition, given the low rate of return migration an important policy goal should be incentivizing the return of emigrants to prevent permanent loss of educated labor force.

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A APPENDICES

Variable name	Definition	Source
Dependent variable		
Intention to migrate	Do you intend to move abroad in the next 12 months? Equals 1 if the answer is affirmative, otherwise 0.	LiTS IV
Independent variables		
Male	Equals 1 if the respondent is male, 0 otherwise.	LiTS IV
Education	What is the highest education level you completed? 1-No degree, 2-Primary education, 3-Lower secondary education, 4-(Upper) Secondary education, 5-Post-secondary non-tertiary education, 6-Tertiary education (not a university diploma), 7-Bachelor's degree or more, 8-Master's degree or PhD	LiTS IV
Age	Age of the respondent.	LiTS IV
Married	Equals 1 if the respondent is married, 0 otherwise.	LiTS IV
Take risk	Please rate your willingness to take risks, in general, on a scale from 1 to 10, where 1 means that you are not willing to take risks at all, and 10 means that you are very much willing to take risks.	LiTS IV
Experience migration	Does this household have any current or former member who left the household to live abroad for at least 3 months? Equals 1 if the answer is affirmative, otherwise 0.	LiTS IV

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Afford holiday	In general, could your household afford the following if it wanted to: Each year, a one-week holiday out of home, including stay in second home, country house or at friends or relatives. The variable equals 1 if the answer is affirmative, otherwise 0.	
Trust institutions	To what extent do you trust each of the following institutions: the presidency, the government, regional government, local government, the parliament, courts, political parties, armed forces, the police, banks, foreign investors, religious institutions, universities and public health authorities. 1-Complete distrust to 5-Complete trust. Aggregate of individual institutional variables.	LiTS IV
Live better	My household lives better nowadays than around 4 years ago. 1-Strongly disagree to 5-Strongly agree	LiTS IV
Political instability	I am concerned about political instability affecting North Macedonia in the next year. 1-Strongly disagree to 5-Strongly agree	LiTS IV

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OVERVIEW OF THE NEW CURRICULUM OF 'CIVIL ENGINEERING / STRUCTURAL' PROGRAM

CURRICULUM VERSION 2026

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ABSTRACT

The 2026 curriculum for the "Civil Engineering / Structures" study program introduces significant upgrades to ensure alignment with modern advancements in civil engineering. These improvements address the evolving demands of design, structural detailing, and construction management. The reorganization is intended to enhance student preparation for emerging challenges in the construction field.

Upon completion of the three-year first-cycle program, graduates earn the title Civil Engineer – Bachelor in Structural Engineering, while upon completing the two-year second cycle program they earn the title Civil Engineer – Master in Structural Engineering

This paper details the critical advancements done in part of the 2026 curriculum, with a special focus on new components that make the program current, clear, and appealing for both Bachelor and Master level students.

Keywords: Curriculum development, Civil Engineering, structural engineering, bachelor's and master's degree

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7 Introduction

The 2026 curriculum for the Construction / Structures Bachelor program introduces a modernized and strategically reorganized framework designed to reflect current advancements in civil engineering practice. Developed to better prepare students for emerging professional demands in design, structural analysis, and construction management, the new curriculum emphasizes clarity, coherence, and technological integration. Upon completion of the three-year first-cycle program, graduates earn the title Civil Engineer – Bachelor in Structural Engineering, while upon completing the two-year second cycle program they earn the title Civil Engineer – Master in Structural Engineering.

The curriculum maintains compliance with European Higher Education Area standards, consisting of 180 ECTS credits distributed evenly across six semesters of the 1st cycle of studies and 120 ECTS credits distributed across the four semesters of the 2nd cycle of studies.

A key update in the 2026 curriculum upgrade is the introduction of a modular organizational system. Eight subject modules—classified as either Core or Professional types - structures the program's knowledge areas and skill development. This modularization enhances curriculum transparency and supports a logical distribution of courses across semesters. Workload analyses show that the greatest concentration of credits lies within the Structures and Engineering modules which represent the courses related thoroughly with the theoretical and practical aspects of the engineering profession.

The newly introduced BIM and INF module represents a significant curricular enhancement, embedding digital competencies and contemporary informatics tools into engineering education. Through multiple INF and BIM focused courses, students gain essential skills for addressing multidisciplinary challenges within modern design and construction environments by the use of most recent advances in digital technology.

Course classification follows both module type and academic purpose. Core modules supply foundational competencies, particularly during the first year, while Professional modules dominate the later semesters, enabling specialization and applied problem-solving. Across the full Bachelor cycle of studies, the curriculum comprises 41% Core courses and 59% Professional ones, while for the Masters cycle of studies, the curriculum comprises 43% of Core courses and 57% Professional ones. Progression within the curriculum is governed by prerequisite structures that ensure mastery of fundamental concepts before advancing to higher-level professional coursework. Course codes, credit assignments, and prerequisite pathways are systematically defined to support academic clarity and student success.

Overall, the 2026 curriculum provides a framework that strengthens engineering foundations, enhances professional competencies, and incorporates modern technological tools, thereby better preparing Bachelor and Master students for the evolving demands of the construction and structural engineering sectors.

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8 Overview of curriculum upgrades

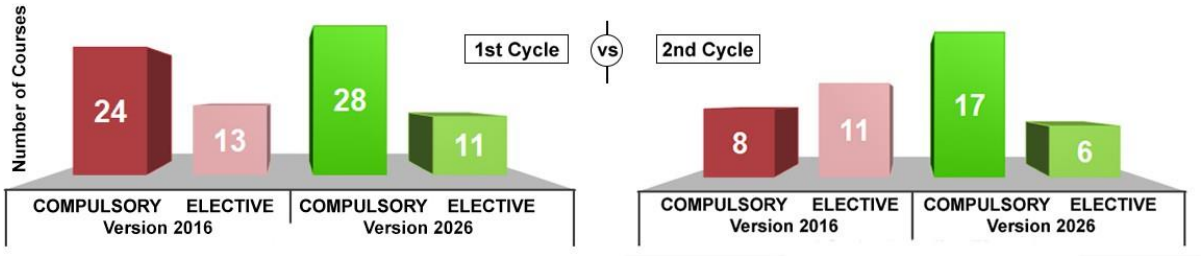
8.1 ECTS Credits and Program Duration

In accordance with the updated curriculum, the Bachelor-level (Cycle 1) studies span 3 years, divided into 6 semesters, in line with European Higher Education Area standards. Each semester accounts for 30 ECTS credits, culminating in a total of 180 ECTS credits upon completion of all six semesters.

Each ECTS credit represents 30 hours of student workload, including both classroom instruction and independent study. Detailed breakdowns of the required student workload for individual courses are provided in the respective course syllabi.

8.2 Course Structure

Students must complete a total of 39 courses during the first cycle under the 2026 curriculum. Of these, 28 are classified as "Compulsory" and 11 as "Elective." The curriculum reflects a slight increase in the total number of courses compared to the 2016 version, as illustrated in the charts of figure 1 below.



a) b)

Figure 1: Number of courses on: a) 1st Cycle of studies; b) 2nd Cycle of studies

8.3 Modules and Course distribution

A major upgrade in the 2026 curriculum is the organization of courses into subject modules (figure 2). This modular approach clarifies the curriculum's structure, strengthens connections between courses, and streamlines the allocation of courses across semesters. This organization is adopted to both Bachelor's and Master's cycles.

Courses are also grouped according to the nature of their module, resulting in "Core" and "Professional" categories. The Mathematics, Language, and Engineering modules are considered Core, while the remaining modules are Professional. Core modules provide foundational knowledge essential for subsequent professional courses. Professional modules build upon this base, expanding students' expertise and their ability to apply core concepts in specialized scenarios.

Both Bachelor's and Master's cycles are comprised of 8 distinct subject modules, each defined by its scope of knowledge, subject area, and the skills it imparts. Courses are assigned to modules based on these criteria. Additionally, modules are categorized as either "Core" or "Professional," as indicated in the corresponding table, with color-coding used consistently throughout the curriculum tables (shown in figures 4 through 7) for clarity.

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Module	Type of Module	Mod	Color Key
Mathematics	Core	MAT	
Informatics	Core	INF	
BIM	Professional	BIM	
Engineering	Core	ENG	
Construction	Professional	CON	
Geotechnics	Professional	GEO	
Diploma Thesis	Professional	DT	

Figure 2: Classification of courses in modules and types

Figure 3 illustrates the distribution of credits among the subject modules. Observing this figure, one can notice that the greatest academic workload is concentrated in the Structures (STR), Engineering (ENG), Mathematics (MATH), and Building Information Modelling (BIM) modules. Core courses predominate in the first year of both Bachelor and Master cycles, while Professional courses are more prominent from the second year onward. In the 1st cycle of studies, 41% of courses are Core and 59% are Professional. Similarly, in the 2nd Cycle, 43% of courses are Core and 57% are Professional. Figure 3 shows another classification of courses Courses, i.e. "Compulsory" versus "Elective." Elective courses offer students the opportunity to shape their technical and academic profiles from early in their studies. In the 1st cycle, 72% of courses are compulsory and 28% are elective, with both types present in nearly every semester. Similarly, in the 2nd cycle, 74% of courses are compulsory and 26% are elective. The left graphs of figure 3 illustrate the distribution of subject modules and credits across the six semesters, confirming that the total 180 credits are evenly allocated, with 30 credits per semester.

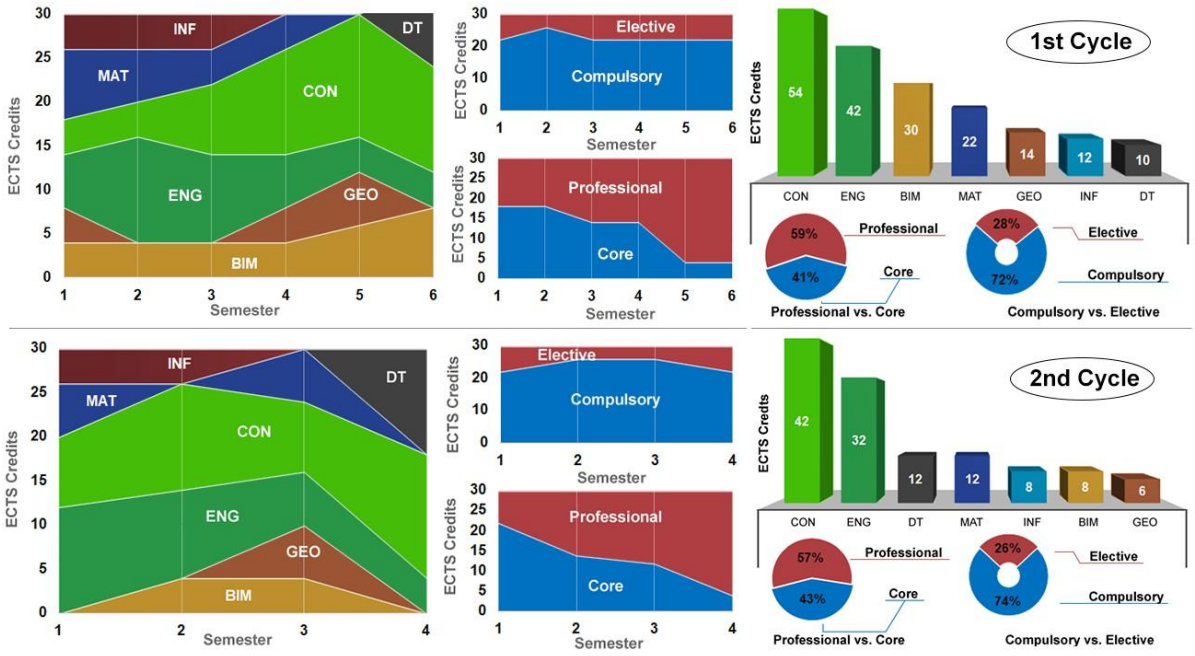

Figure 3: Distribution of course modules along semesters of both Bachelor and Master studies

Of particular important in the new curriculum 2026 is the introduction of the "BIM" and "INF" modules, which integrate modern technological and informatics advances into student

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education. These modules include multiple courses designed to equip students with the ability to utilize contemporary technological tools, vital for solving multidisciplinary engineering challenges.

8.4 Course Linking, Coding, and Crediting

The 2026 curriculum interlinks courses such that students must pass prerequisite courses from earlier semesters before progressing to linked courses in later semesters. This structure is depicted in a graphical representation in figures 5 and 7 below.

In addition, each course is assigned a specific number of credits based on its workload and nature, with corresponding course codes. These course codes and ECTS credits are shown in figures 4 and 6 below.

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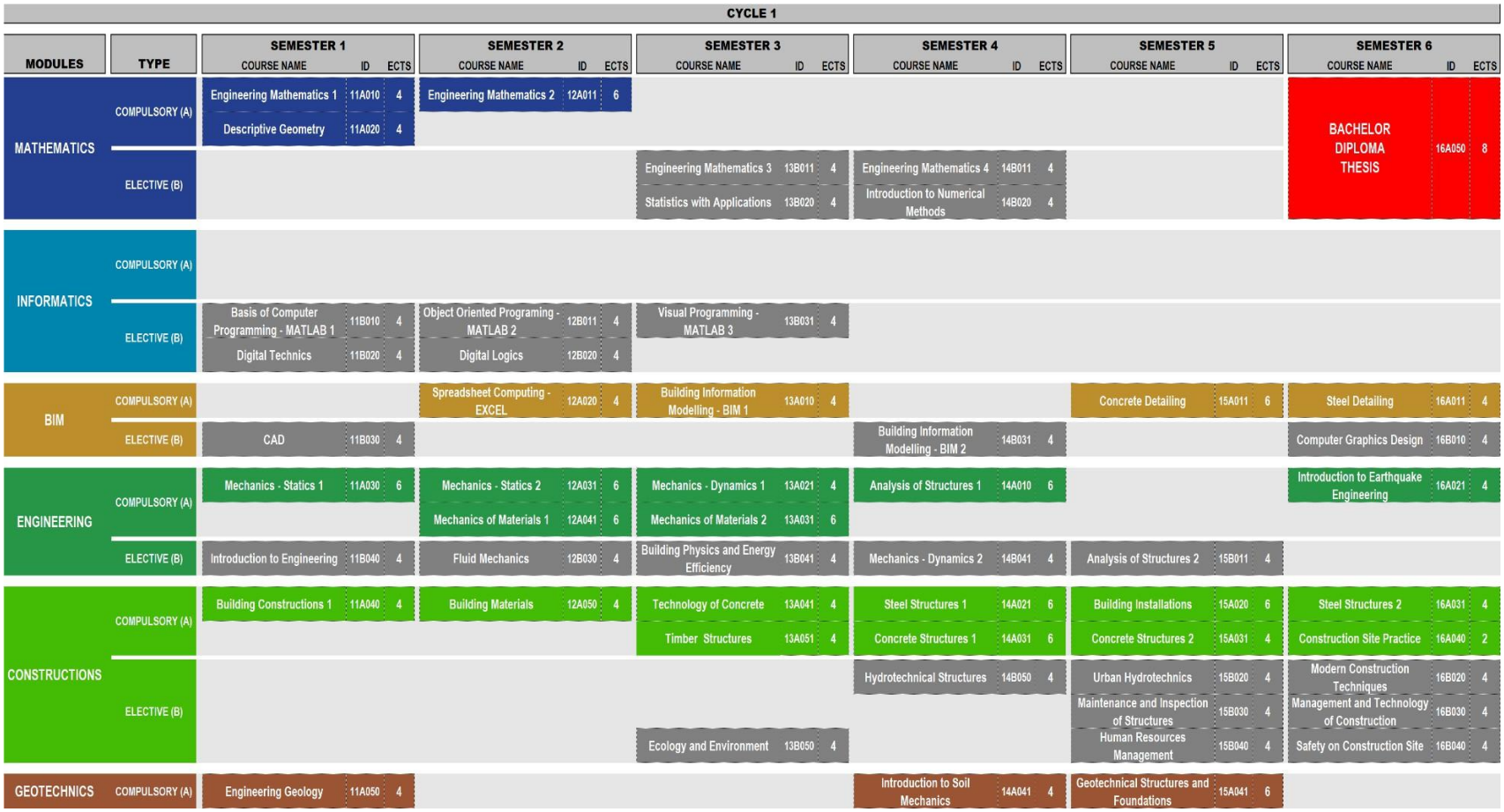
CYCLE 1
MODULES
TYPE
SEMESTER 1
COURSE NAME ID ECTS
SEMESTER 2
COURSE NAME ID ECTS
SEMESTER 3
COURSE NAME ID ECTS
SEMESTER 4
COURSE NAME ID ECTS
SEMESTER 5
COURSE NAME ID ECTS
SEMESTER 6
COURSE NAME ID ECTS
MATHEMATICS
COMPULSORY (A)
Engineering Mathematics 1 11A010 4
Descriptive Geometry 11A020 4
Engineering Mathematics 2 12A011 6
BACHELOR DIPLOMA THESIS 16A050 8
ELECTIVE (B)
Engineering Mathematics 3 13B011 4
Statistics with Applications 13B020 4
Engineering Mathematics 4 14B011 4
Introduction to Numerical Methods 14B020 4
INFORMATICS
COMPULSORY (A)
ELECTIVE (B)
Basis of Computer Programming - MATLAB 1 11B010 4
Digital Technics 11B020 4
Object Oriented Programing - MATLAB 2 12B011 4
Digital Logics 12B020 4
Visual Programming - MATLAB 3 13B031 4
BIM
COMPULSORY (A)
Spreadsheet Computing - EXCEL 12A020 4
Building Information Modelling - BIM 1 13A010 4
Concrete Detailing 15A011 6
Steel Detailing 16A011 4
ELECTIVE (B)
CAD 11B030 4
Building Information Modelling - BIM 2 14B031 4
Computer Graphics Design 16B010 4
ENGINEERING
COMPULSORY (A)
Mechanics - Statics 1 11A030 6
Mechanics - Statics 2 12A031 6
Mechanics of Materials 1 12A041 6
Mechanics - Dynamics 1 13A021 4
Mechanics of Materials 2 13A031 6
Analysis of Structures 1 14A010 6
Introduction to Earthquake Engineering 16A021 4
ELECTIVE (B)
Introduction to Engineering 11B040 4
Fluid Mechanics 12B030 4
Building Physics and Energy Efficiency 13B041 4
Mechanics - Dynamics 2 14B041 4
Analysis of Structures 2 15B011 4
CONSTRUCTIONS
COMPULSORY (A)
Building Constructions 1 11A040 4
Building Materials 12A050 4
Technology of Concrete 13A041 4
Timber Structures 13A051 4
Steel Structures 1 14A021 6
Concrete Structures 1 14A031 6
Building Installations 15A020 6
Concrete Structures 2 15A031 4
Steel Structures 2 16A031 4
Construction Site Practice 16A040 2
ELECTIVE (B)
Hydrotechnical Structures 14B050 4
Urban Hydrotechnics 15B020 4
Maintenance and Inspection of Structures 15B030 4
Human Resources Management 15B040 4
Modern Construction Techniques 16B020 4
Management and Technology of Construction 16B030 4
Safety on Construction Site 16B040 4
Ecology and Environment 13B050 4
GEOTECHNICS
COMPULSORY (A)
Engineering Geology 11A050 4
Introduction to Soil Mechanics 14A041 4
Geotechnical Structures and Foundations 15A041 6

Figure 4: Course crediting, coding and distribution along the 6 semesters of the 1st (Bachelor) cycle of studies

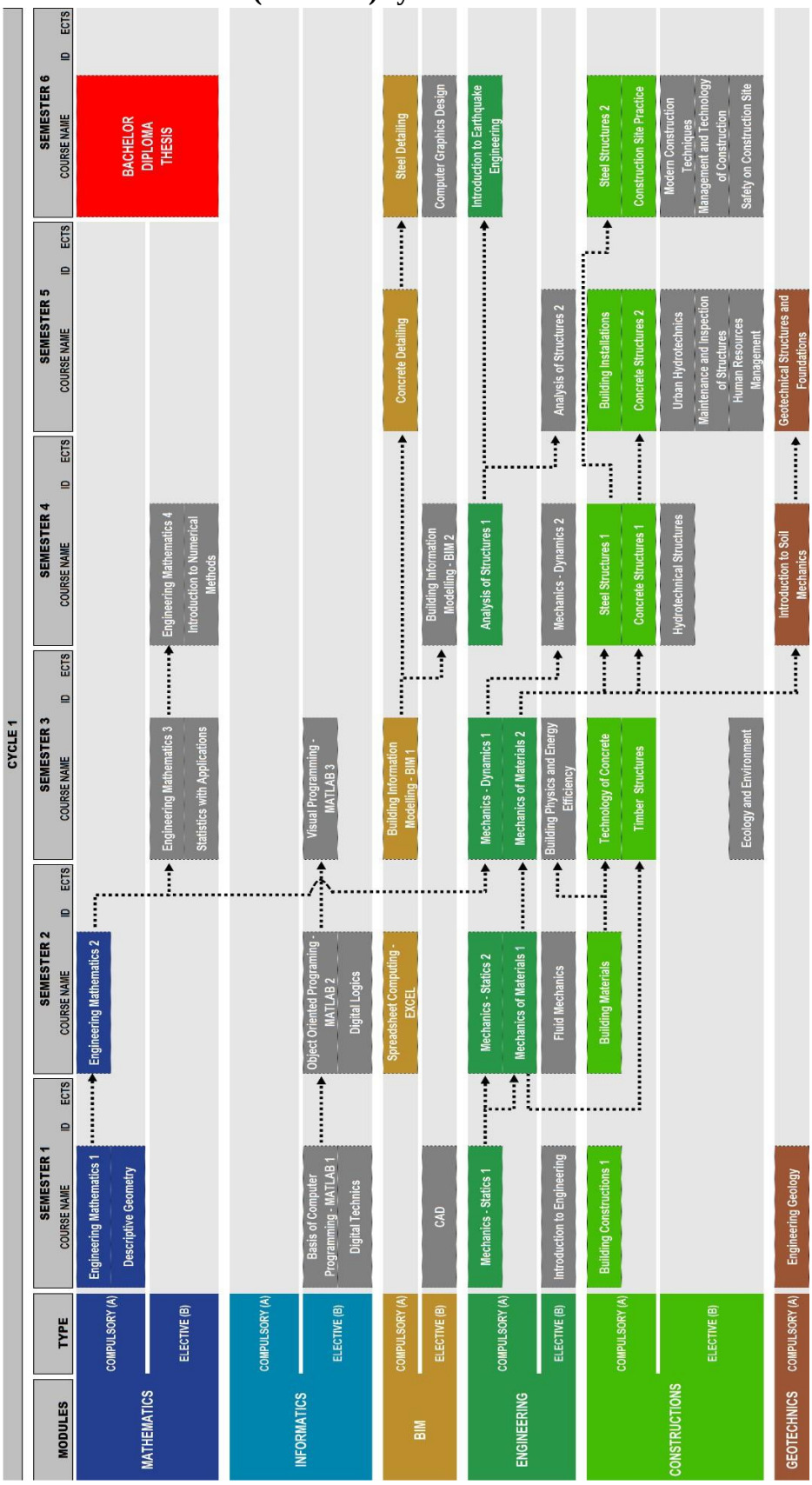

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Figure 5: Course linking and distribution along the 6 semesters of the 1st (Bachelor) cycle of studies

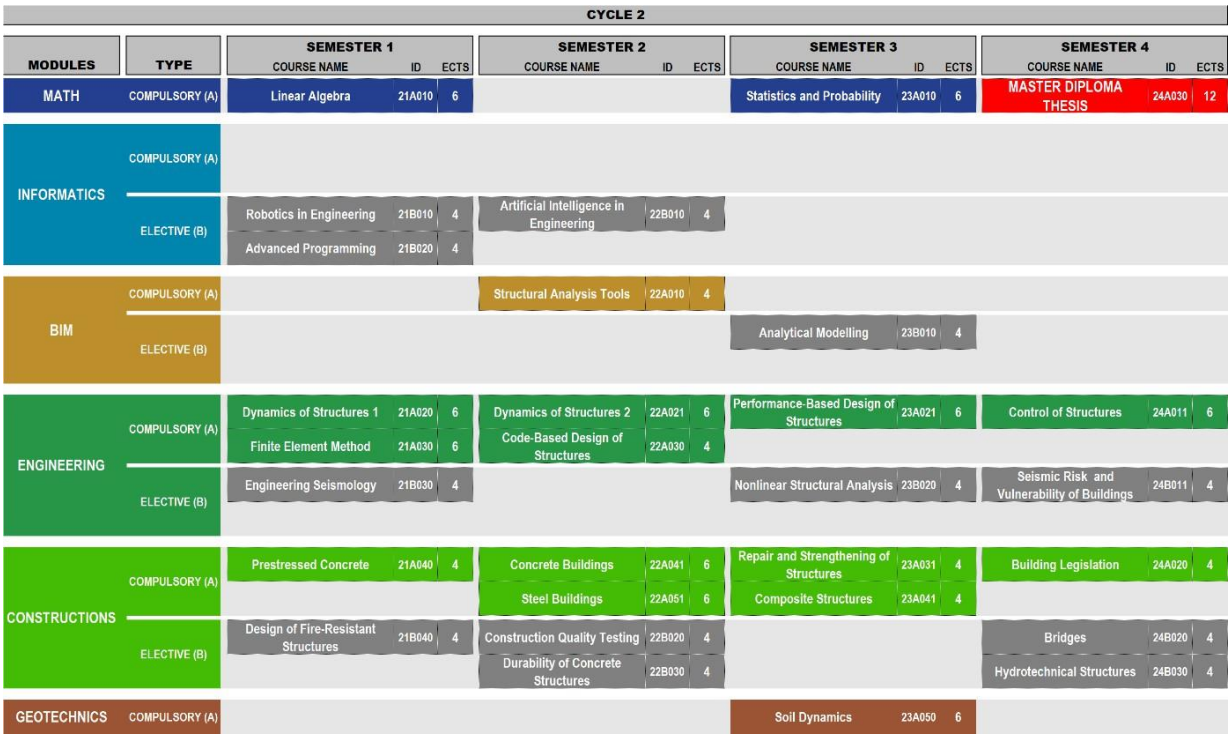

Figure 6: Course crediting, coding and distribution along the 4 semesters of the 2nd (Master) cycle of studies

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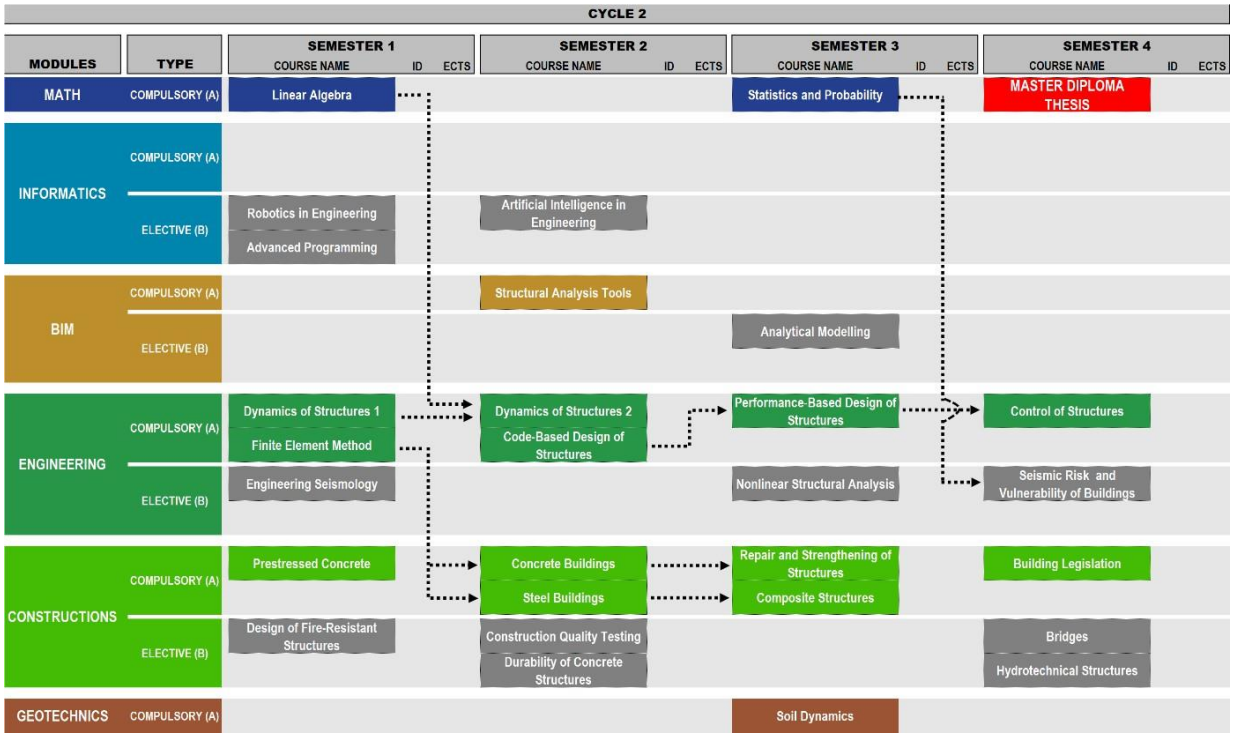

Figure 7: Course linking and distribution along the 4 semesters of the 2nd (Master) cycle of studies

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THE INSTITUTE OF DECLARING A MISSING PERSON DEAD AS A MODE OF TERMINATION OF LEGAL CAPACITY

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Abstract

The institute of declaring a missing person dead as a mode of termination of legal capacity is a fundamental legal mechanism applied when an individual disappears and no information exists regarding their survival. In civil-law systems, this institute produces the same consequences as biological death, including the termination of legal capacity, dissolution of marriage, and the opening of succession. According to the Law on Obligations of the Republic of North Macedonia, the legal capacity of a natural person terminates with their death, or with their being declared dead. In the Republic of North Macedonia, the institute is expressly regulated by the Law on Non-Contentious Procedure, which sets detailed general and specific presumptions and procedural safeguards based on prolonged absence and lack of information. A similar structure is found in Kosovo, where the Law on Out Contentious Procedure adopts the same conditions and temporal requirements.

In Italy, the institute is regulated by the Italian Civil Code, which allows the declaration of a person as missing after two years without news, and the declaration of death after ten years. If the missing person reappears or if their existence is reliably established elsewhere, the decision declaring the person as missing becomes legally ineffective. In the United Kingdom, the Presumption of Death Act 2013 governs the judicial declaration of death, while the Guardianship (Missing Persons) Act 2017 authorizes temporary administration of the missing person's property. Convention on the Establishment of Death in Certain Cases, prepared by the International Commission on Civil Status (ICCS Convention No. 10) regulates the procedures for establishing death in cases where a person has disappeared and the body cannot be recovered, specifying how the act of death is to be registered and how such decisions are to be recognized among the contracting states. The Council of Europe

Recommendation CM/Rec (2009)12 clarifies and strengthens the notion of a "missing person", encourages clear and efficient procedures, and reinforces cooperation among states in disappearance cases. Although legal structures differ, core elements remain consistent across jurisdictions: prolonged absence, lack of communication, judicial scrutiny, and mechanisms to revoke the decision if the person reappears.
Keywords: *legal capacity termination, presumed death, missing persons, procedural safeguards.*

1. Introduction

The institute of declaring a missing person dead is a legal institute designed to address circumstances in which an individual disappears and their fate cannot be established. Such uncertainty disrupts civil-status records, succession procedures, and family relations, requiring structured legal mechanisms to restore stability. Modern legal systems, in addition to regulating physical death, also regulate the so-called presumed death, which in our legislation is governed by a set of legal norms constituting the institution of declaring a missing person dead[1]. Presumed death, once established by a court decision, produces the same legal effects as the occurrence of biological death[2].

Legal capacity continues for as long as the natural person is alive and ceases upon his or her death or upon a judicial declaration as dead[3]. The declaration of a missing person as dead, that is, the establishment of presumed death, likewise entails the termination of the legal subjectivity of the natural person.

2. The legal framework governing the institute of declaring a missing person dead under Macedonian law

In Macedonian objective law, presumed death, or the institution of declaring a missing person dead, is regulated by the Law on Non-Contentious Procedure[4]. The procedure for declaring a missing person dead constitutes a special non-contentious procedure aimed at regulating personal status matters[5]. According to Professor F. Brestovci, non-contentious status proceedings are those proceedings in which certain issues related to the personal (status) condition of legal subjects are resolved[6].

According to Professors R. Zhivkovska and T. Przheska, in order for a person to be declared dead, two legal prerequisites must be fulfilled: 1. the disappearance of the person (or persons) as a

[1] Article 81 of the Law on Non-Contentious Procedure, Official Gazette of the Republic of Macedonia, No. 9/08 and 77/2018, available at: https://jpacademy.gov.mk/wp-content/uploads/2022/08/zakon_za_vonparicna_postapka.pdf.
[2] See: A. Aliu, *Edrejta civile*, Prishtinë, 2013, 239.
[3] A. Aliu, *op. cit.,* 236.
[4] This refers to the provisions from Articles 74 to 87 of the Law on Non-Contentious Procedure …
[5] Thus: А. Јаневски, Т. Зороска – Камиловска, *Граѓанско процесно право, Книга втора, Вонпарнично право*, Скопје, 2010, 77.
[6] F. Brestovci, *E drejta e procedurës civile II*, Universiteti I Prishtinës, Fakulteti juridik, Prishtinë, 2004, 245.

primary, necessary, and general prerequisite; and 2. the fulfillment of one of the four special prerequisites prescribed by law[7]. Accordingly, Article 81 of the Law on Non-Contentious Procedure enumerates the special prerequisites, as follows: 1. A person shall be considered missing if no information whatsoever concerning his or her life has been available during the last five years and if at least sixty years have elapsed since his or her birth; 2. A person shall be considered missing if no information whatsoever concerning his or her life has been available during the last five years and if there are grounds to believe that the person is no longer alive; 3. A person who disappeared in a shipwreck, traffic accident, fire, flood, earthquake, or other circumstances involving mortal danger shall be considered missing if no information whatsoever concerning his or her life has been available for at least six months from the day on which the danger ceased and 4. A person who disappeared during a state of war shall be considered missing if no information whatsoever concerning his or her life has been available for one year from the day on which hostilities ceased. The time limits prescribed for declaring a missing person dead shall be calculated from the day on which, according to the last available information, the missing person was unquestionably alive. If the exact day cannot be determined, these time limits shall begin to run from the end of the month or, respectively, from the end of the year in which, according to the last available information, the missing person was alive[8].

For the declaration of a missing person who is a citizen of the Republic of North Macedonia as dead, the competent court shall be the court in the Republic of North Macedonia in whose territorial jurisdiction the missing person had his or her domicile at the time of disappearance[9].

Pursuant to the provisions of the Law on Non-Contentious Procedure, a motion for declaring a missing person dead may be submitted by any person who has a legal interest therein, as well

[7] See: Р. Живковска, Т. Пржеска, *Граѓанско право - општ дел*, Европа 92, Скопје, 2021, 75.
[8] See: Article 81, paragraph 3, Law on Non-Contentious Procedure…
[9] *"If a citizen of the Republic of Macedonia did not have a place of residence at the time of disappearance in the Republic of Macedonia, or if such place cannot be established, the locally competent court shall be designated by the Supreme Court of the Republic of Macedonia*," Article 75, Law on Non-Contentious Procedure…

as by the public prosecutor when property interests of the Republic are concerned[10]. The right to initiate proceedings for declaring a missing person dead, in accordance with the Law on Non-Contentious Procedure, also belongs to the State Attorney when the protection of a certain state interest of a proprietary nature is involved[11]. Legal interest in initiating proceedings for declaring a missing person dead, in accordance with statutory provisions, is vested in: the spouse of the missing person, his or her children, parents, other relatives, as well as persons who are not related to the missing person but who may be called to inherit, etc[12]. Heirs have a legal interest since they are entitled to inheritance, the spouse has a legal interest because, by the declaration of death of the missing spouse, the marriage is dissolved and a new marriage may be concluded[13]. Furthermore, a legal interest is held by the creditor of the missing person, since only the heirs may satisfy his or her claim.

The content of the motion for initiating proceedings for declaring a missing person dead is determined by statutory provisions[14].

If the court establishes that the conditions for initiating the proceedings have been fulfilled, it shall publish a notice stating the essential circumstances of the case and shall invite the missing person, as well as any other person who has knowledge of his or her life, to appear before the court within a period of three months from the publication of the notice in the Official Gazette of the Republic of North Macedonia, indicating that upon the expiry of that period the missing person shall be declared dead. Upon the expiry of the prescribed period, if the missing person does not appear, the Centre for Social Work shall be notified in order to appoint a guardian for the missing person, as well as the public prosecutor[15].

If the material-law prerequisites are fulfilled, the court shall

[10] See: Article 76, Law on Non-Contentious Procedure…
[11] Ibid.
[12] Thus: А. Јаневски, Т. Зороска – Камиловска, *Граѓанско процесно право, Книга втора, Вонпарнично право*, Скопје, 2010, 91.
[13] See: A. Aliu, *op. cit.,* 238.
[14] *"The motion for declaring a missing person dead shall contain the facts relevant for the adoption of the decision; if the motion is submitted by a person other than the public prosecutor, it shall also state the legal interest of the applicant for declaring the missing person dead*". Article 77, Law on Non-Contentious Procedure…
[15] See: Article 82, paragraphs 1,2, Law on Non-Contentious Procedure…

adopt a decision by which the missing person is declared dead[16].

With regard to the time of death of the missing person, the Law on Non-Contentious Procedure prescribes that, in the decision by which the missing person is declared dead, the day shall be indicated and, where possible, also the hour, which shall be considered as the time of death of the missing person[17]. Furthermore, as the day of death, the Law considers the day on which, on the basis of the evidence adduced, it may be believed that the missing person died, that is, the day which the missing person most probably did not survive.

Proceeding from the aforementioned provisions, Professors A. Janevski and T. Zoroska-Kamilovska emphasize that the decision declaring a missing person dead has a declaratory nature and, at the same time, also has constitutive effect. The Professors hold this view because the decision declaring a missing person dead leads to certain legal changes in the material-law relations in which the missing person was a subject. By the decision, the presumed death of the missing person is established, whereby the person is deemed to have died not as of the day on which the decision becomes final, but as of the day indicated in the decision as the day of death[18].

The decision declaring a missing person dead essentially contains only a presumption of the death of the missing person, and this presumption exists until the contrary is proven. Even after the publication of the decision, the contrary may be proven. An interested person and the public prosecutor may request an amendment of the decision if they claim that the person died at a time different from that indicated in the decision or that the person is not dead but is still alive. It is understood that the assertion as to whether the person is dead or not may also be made by the missing person himself or herself if he or she appears before the court[19]. In such a case, once the court establishes the identity of the person, it shall, without further proceedings, revoke its decision declaring that person dead[20].

[16] Thus: А. Јаневски, Т. Зороска – Камиловска, *op. cit.,* 93.
[17] See: Article 82, Law on Non-Contentious Procedure…
[18] Thus: А. Јаневски, Т. Зороска – Камиловска, *op. cit.,* 93.
[19] For the institute of declaring a missing person dead, see: Gams A., *Hyrje në të Drejtën Civile*, Prishtinë, 1972. 118.
[20] See: Article 83, Law on Non-Contentious Procedure…

The marriage of the person which ceased as a result of the declaration of death shall not be restored, regardless of whether the spouse of the missing person has concluded a new marriage. As regards the restitution of the property that has been distributed among the heirs, the person shall have to bring an action if the heirs do not voluntarily agree to return it[21]. In the latter case, if it is established that the missing person declared dead is alive or died on a different day than the one determined in the court decision, the court, upon a motion filed by any person having a legal interest, the public prosecutor, or the State Attorney, after conducting the proceedings, shall revoke or amend its decision declaring the missing person dead[22]. Professors A. Janevski and T. Zoroska-Kamilovska consider that the use of the statutory term "revocation" is inappropriate, since, in their view, in this case it would be more appropriate to use the term "setting aside." The Professors emphasize that, in law, revocation constitutes a sanction related to an unlawful decision, whereas in the present case it does not concern an unlawful decision[23].

Pursuant to the Law, the court is obliged to deliver the decision declaring the missing person dead to the competent civil registrar for entry in the register of deaths[24], as well as to the court competent for the distribution of the estate of the missing person. As regards the decision on the revocation of the decision declaring the missing person dead, the court which adopted that decision shall also deliver it to the Centre for Social Work.

3. International instruments and comparative legal overview of the institute of declaring a missing person dead

Within the examination of the legal regime of presumed death, particular importance should be attached to the **Convention on the Establishment of Death in Certain Cases**[25], prepared by the International Commission on Civil Status (ICCS Convention No. 10) and signed in Athens on 14 September 1966. At present,

[21] К. Чавдар, *Закон за вонпарнична постапка, со објаснувања, примери на поднесоци, судска практика и предметен регистар*, Академик, Скопје, 2008, 74-75.
[22] See: Article 84, Law on Non-Contentious Procedure…
[23] Thus: А. Јаневски, Т. Зороска – Камиловска, *op. cit.,* 93.
[24] See: Article 87, Law on Non-Contentious Procedure…
[25] Convention (No. 10) relating to the Establishment of Death in Certain Cases, International Commission on Civil Status (ICCS), Athens, 1966, available at: https://www.ciecl.org/ConventionsPDFEN/Conv_EN_10.pdf.

it is the only international legal instrument dealing with aspects of civil law concerning missing persons. This Convention regulates only cases in which death may be regarded as certain and, consequently, does not cover cases of missing persons whose death may be considered probable or uncertain.

With regard to presumed death, the Convention provides that: *where the body of the missing person cannot be found but, in light of all the circumstances, it may be taken as certain that the person is dead, the judicial authority or the administrative authority competent for that purpose shall declare the person dead: 1. if the disappearance occurred on the territory of the State to which that authority belongs or during travel on board a ship or an aircraft registered in that State; or 2. if the person was a national of that State or had his or her domicile or habitual residence on its territory*[26]. From these provisions it may be concluded that the Convention applies only in cases where the death of the missing person is certain, and not to missing persons whose death cannot be regarded as certain.

Due to the increased mobility caused by the development of travel and the prolongation of stays abroad, as well as the increased risk and recurrence of terrorist attacks and man-made or natural disasters, as a consequence, inter alia, of climate change, a need emerged for the above-mentioned provisions on presumed death contained in the Convention to be supplemented. In those States where statutory regulation of presumed death already existed, a need arose for such regulation to be further harmonised with the legislation of the member States of the Council of Europe. With the aim of implementing additional provisions on presumed death for the aforementioned reasons, the Council of Europe established a Working Group on Missing Persons (CJ-FA-GT1), which was formed under the authority of the European Committee on Legal Co-operation (CDCJ). Its task was to prepare a Recommendation with the aim of providing assistance to the governments of the member States in dealing with all cases of presumed death[27].

[26] See: Article 1, Convention (No. 10) relating to the Establishment of Death in Certain Cases…

[27] Principles concerning Missing Persons and the Presumption of Death, Recommendation CM/Rec(2009)12 and Explanatory Memorandum, Council of Europe, available at: https://rm.coe.int/16807096bd. "*In essence, the*

According to **Recommendation CM/Rec(2009)12**, *a "missing person" is a natural person whose existence has become uncertain, having disappeared without trace and in respect of whom there is no evidence that he or she is alive*[28].

Pursuant to the Recommendation, if the death of the missing person is uncertain and his or her disappearance cannot reasonably be attributed to any cause other than death, the missing person may be declared dead, in which case death shall be presumed to be both certain and probable[29].

In accordance with the Recommendation, the competent authority for declaring a missing person dead shall be: 1. the authority of the State of which the missing person is a national or in which he or she had domicile or habitual residence on its territory, 2. the authority of the State in which the missing person was reported missing, and 3. in addition to these two situations, the Recommendation provides that competence may also lie with the State in which the ship on board which the disappearance occurred is registered[30].

According to the Recommendation, if the person who has been declared dead returns or if information emerges that he or she is still alive, the member States should provide for measures aimed at annulling the decision declaring the death of that person[31]. In this respect, a request for annulment of the decision on presumed death may be submitted by the person whose presumed death has been declared, or by any person or authority having a legal interest, as well as by the authority designated by the State for that purpose.

In the **United Kingdom**, pursuant to the Presumption of Death Act 2013[32], a missing person shall be presumed dead if seven years have elapsed since his or her disappearance. This means

Recommendation aims to restore a fair balance between two categories of interests: the interests of missing persons and the interests of persons who are legally entitled to seek a declaration of death of the missing person". The Recommendation was prepared by the working group and adopted by the Committee of Ministers on 9 December 2009, Ibid.

[28] Part I – Recommendation CM/Rec(2009)12…

[29] Part II – Principle 1, Recommendation CM/Rec(2009)12…

[30] Principle 2, Recommendation CM/Rec(2009)12…

[31] Principle 7, Recommendation CM/Rec(2009)12…

[32] Presumption of Death Act 2013, UK Public General Acts, available at: https://www.legislation.gov.uk/ukpga/2013/13/contents.

that, in addition to the care and anguish suffered, there is also a serious consequence in that, without confirmation of death, the property of the missing person is in practice "frozen". Such regulation undoubtedly gives rise to certain implications where the missing person has financial assets, bank accounts, and similar property which, under this Act, are frozen[33].

In such cases, the family of the missing person, in accordance with the law applicable in England and Wales, has the right to submit an application to the courts for a declaration that the missing person is dead. The application submitted to the High Court for a declaration of death of the missing person may be filed by the spouse, the civil partner of the missing person, a parent, a child, a brother or sister, as well as by persons who have a legal interest therein[34].

Pursuant to the Presumption of Death Act 2013, following the court decision by which the missing person is declared dead, the marriage or the civil partnership of the missing person is dissolved, thereby enabling the surviving partner to plan his or her private life[35].

Under this Act of 2013, a missing person is considered to be *a natural person whose existence has become uncertain, having disappeared without trace and in respect of whom there is no evidence that he or she is alive*[36].

As regards the court decision, it must be based on the court's conviction that, in light of the circumstances, the person has disappeared either because he or she has died or because it has not been known that the person is alive for at least seven years[37].

With regard to the time of death, this shall be determined by the High Court. If the court is satisfied that the missing person died on the date of disappearance, that date shall be regarded as the date of death. However, if the court is satisfied that the missing

[33] "When a family member is missing, but their estate is frozen" , available at: https://www.bishopandsewell.co.uk/campaigns/presumption-of-death/ (20.10.2025).
[34] Article 1, paragraph 4,5, Applying for a Declaration, Presumption of Death Act 2013…
[35] Bishop & Sewell LLP, Available at: https://www.bishopandsewell.co.uk/ (11.10.2025).
[36] Article 2, paragraph 1, Presumption of Death Act 2013…
[37] Article 1, paragraph 1, Presumption of Death Act 2013…

person died but the exact date of death is uncertain, it shall order that the date of death be the last day of the period during which it was believed that the missing person had died. If the court is not satisfied that the missing person has died, but is satisfied that it has not been known that the person was alive during the last seven years, then the date of death shall be the day following the expiry of seven years from the disappearance (that is, from the day on which the person was last known to be alive)[38]. In the event that the application is granted, the court shall notify the Registrar General for England and Wales, for the purpose of entering the relevant details in the Register of Presumed Deaths, upon which the Registrar shall issue a certificate of presumed death[39].

Likewise, the Act which regulates, or supplements, the already established legal regime for declaring a missing person dead, with the aim of eliminating the negative financial implications affecting the property of the missing person that remained frozen for seven years, is, in England and Wales, the Guardianship (Missing Persons) Act 2017, known as "Claudia's Law". This Act allows for the appointment of a guardian by the court who shall manage the property of the missing person[40].

The Guardianship (Missing Persons) Act 2017 provides that a person shall be regarded as "missing" where: *a) the person is absent from his or her usual place of residence, b) the person is absent from his or her usual day-to-day activities, and c) one of the first two conditions is satisfied*[41]. Taking into account that the period of seven years is excessively long due to its financial implications, the Act on guardianship (missing persons) provides for the appointment of a guardian who shall manage the affairs of the missing person where the absence has lasted ninety days or more[42].

If the missing person returns home or is found alive at another

[38] "What Is the Presumption of Death Act 2013?", available at: https://www.thegazette.co.uk/.
[39] Ibid.
[40] Guardianship (Missing Persons) Act 2017 (UK), Code of Practice, fully in force as of 31 July 2019, available at: https://assets.publishing.service.gov.uk/media/5d41a31aed915d09d8945da9/missing-people-code-of-practice.pdf.
[41] Article 1, paragraph 1, Guardianship (Missing Persons) Act 2017…
[42] "Claudia's Law in Force: Helping the Families of Missing People, available at: https://www.kingsleynapley.co.uk/.

location, the guardian shall notify the court that the person should no longer be treated as a missing person, for which purpose the guardian shall submit an application to the court seeking the revocation of the guardianship order.

Pursuant to the Guardianship (Missing Persons) Act 2017, where, within a period of seven years, it becomes probable that the missing person died during that period, the Act provides the possibility for the initiation of proceedings (by way of an application) either for the purpose of proving the death of the missing person or for seeking a declaration of presumed death[43].

In the **Republic of Italy**, the institution of declaring a missing person dead is regulated by the Italian Civil Code[44].

Pursuant to the Civil Code, where a person no longer appears at his or her place of residence or at his or her last known domicile, the court, upon application by the heirs, other legally interested persons, or the public prosecutor, may appoint a curator for the missing person, who shall take care of the conduct of the proceedings and the management of the missing person's property. Where the missing person has a legal representative, there is no need to appoint a curator[45].

After the lapse of two years from the last information concerning the missing person, the legal heirs and other legally interested persons may propose to the court that the person be declared missing[46]. In such a case, the court shall adopt a decision declaring the person missing. Thereafter, the legal heirs, persons having a legal interest, or the public prosecutor may propose to the court that the will of the missing person be opened, provided that a will exists. Persons who seek to administer the property of the missing person are required to provide appropriate security (a bond) before the court, in an amount to be determined by the court[47].

Persons entrusted with the administration of the property of the

[43] When and How is a Missing Person Legally Presumed Dead?, available at: https://www.rochelegal.co.uk.
[44] See: Articles 48–73 of the Italian Civil Code (Codice Civile Italiano), available at: https://www.wipo.int/wipolex/en/legislation/details/16608.
[45] Article 48, Italian Civil Code (Codice Civile Italiano)…
[46] Article 49, Italian Civil Code (Codice Civile Italiano)…
[47] Article 50, Italian Civil Code (Codice Civile Italiano)…

missing person may not alienate, encumber, or otherwise dispose of such property, unless authorised to do so by the court[48].

Pursuant to the Italian Civil Code, where the missing person reappears or where his or her existence at another location is established with certainty, the decision by which the person was declared missing shall cease to have legal effect. In such a case, the temporary administrators of the property shall return the property in full to the missing person, retaining only the profits obtained. Where the disappearance of the person was the result of a voluntary and unjustified abandonment of his or her place of residence or domicile, the person shall lose the right to claim the return of his or her previous property[49]. Under the Italian Civil Code, a missing person shall be declared dead after the lapse of ten years from the last reliable information concerning him or her. Upon an application submitted by the public prosecutor or by a legally interested person, the court shall render a decision declaring the missing person dead[50].

In the **Republic of Kosovo**, the institution of declaring a missing person dead is regulated by the Law on Out Contentious Procedure[51].

Professor A. Aliu, with regard to the declaration of a missing person dead, points out that two prerequisites must be fulfilled: 1) the person must have been absent from his or her place of residence for a certain (long) period of time, and 2) it must be unknown where the person is and whether the person is alive or dead[52].

Article 59 of the Law on Out Contentious Procedure enumerates the conditions that must be satisfied in order for a missing person to be declared dead, namely: 1. where, during the last five years, there has been no information about the missing person and at least sixty-five years have elapsed since his or her birth, 2. where, during the last five years, there has been no information

[48] Article 54, Italian Civil Code (Codice Civile Italiano)…
[49] Article 56, Italian Civil Code (Codice Civile Italiano)…
[50] Article 58, Italian Civil Code (Codice Civile Italiano)…
[51] See: Articles 49–72 of Law No. 03/L-007 on Out Contentious Procedure, Official Gazette of the Republic of Kosovo, Year IV/No. 45/12 January 2009, available at: https://anjf.rks-gov.net/desk/inc/media/F56C5806-4597-416E-BE0D-91CF451E92C2.pdf.
[52] See: A. Aliu, *op. cit.,* 236.

concerning the life of the person and there are grounds to believe that the person is no longer alive, 3. where the person disappeared during a state of war and there has been no information concerning his or her life for one year from the date of entry into force of the peace treaty, or two years from the date on which hostilities ceased, and 4. where the person disappeared in a shipwreck, traffic accident, fire, flood, earthquake, or another immediate life-threatening danger, and there has been no information concerning his or her life for at least six months from the date on which the danger ceased[53].

Pursuant to the provisions of the Law on Out Contentious Procedure, a proposal for declaring a missing person dead may be submitted by any person having a legal interest, as well as by the guardianship authority[54]. For the declaration of a missing person who is a national of the Republic of Kosovo as dead, jurisdiction lies with the court in whose territory the person had his or her domicile at the time of disappearance, and if the person had no domicile, with the court of the person's last residence[55].

According to the Law, upon the declaration of a person as missing, a guardian shall be appointed for the administration of the missing person's property[56].

The court is obliged to deliver the decision declaring the missing person dead to the competent civil registrar for entry in the register of deaths, as well as to the court competent for the distribution of the estate of the missing person, to the guardianship authority, and to the authority responsible for maintaining the real estate register, if the person declared dead owns immovable property[57].

Taken together, these international and comparative legal solutions demonstrate a gradual shift towards a more flexible and pragmatic regulation of presumed death, aimed at reconciling legal certainty with the effective protection of the personal and proprietary interests of missing persons and their families.

4. Conclusions and Recommendations

[53] Article 59, Law No. 03/L-007 on Out Contentious Procedure…
[54] Article 61, Law No. 03/L-007 on Out Contentious Procedure…
[55] Article 60, paragraph 1, Law No. 03/L-007 on Out Contentious Procedure…
[56] Article 56, paragraph 1, Law No. 03/L-007 on Out Contentious Procedure…
[57] See: A. Aliu, *op. cit.,* 239.

This paper examines the legal institute of declaring a missing person dead as a distinct legal category of death. The analysis pays particular attention to the substantive and procedural dimensions of this institute as regulated under Macedonian law, emphasising the legal prerequisites for declaring a missing person dead, the conduct of the non-contentious procedure, and the legal effects arising from a judicial declaration of death. In this context, the paper highlights the declaratory nature of the court decision and its constitutive effects on personal and proprietary legal relations.

The Macedonian legal framework is then placed within a broader international and comparative context through an examination of the Convention on the Establishment of Death in Certain Cases (ICCS Convention No. 10, 1966) and Recommendation CM/Rec(2009)12 of the Council of Europe, as well as the legal solutions adopted in the United Kingdom, Italy and Kosovo. By analysing these international instruments and comparative legal systems, the paper identifies common principles, divergent legislative approaches and emerging trends in the regulation of presumed death, while emphasising the growing need to reconcile legal certainty with the effective protection of the personal and proprietary interests of missing persons and their families. It is recommended that the legal framework continues to evolve in line with broader European developments.

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[2] F. Brestovci, *E drejta e procedurës civile II*, Universiteti i Prishtinës, Fakulteti juridik, Prishtinë, 2004 ;

[3] A. Gams, *Hyrje në të drejtën civile*, Prishtinë, 1972.;

[4] Р. Живковска, Т. Пржеска, *Граѓанско право – општ дел*, Европа 92, Скопје, 2021;

[5] Law on Obligations, Official Gazette of the Republic of Macedonia, No. 18/2001;

[6] Law on Non-Contentious Procedure, Official Gazette of the Republic of Macedonia, No. 9/2008;

[7] А. Јаневски, Т. Зороска – Камиловска, *Граѓанско процесно право, Книга втора, Вонпарнично право,* "Правен факултет Јустинијан Први", Скопје, 2010;

[8] К. Чавдар, *Закон за вонпарнична постапка, со објаснувања, примери на поднесоци, судска практика и предметен регистар*, Академик, Скопје, 2008;
[9] Convention (No.10) relating to the establishment of death in certain cases, The International Commission on Civil Status (ICCS), Athens, 1966, available at: https://www.ciec1.org/ConventionsPDFEN/Conv_EN_10.pdf;
[10] Principles concerning missing persons and the presumption of death, Recommendation CM/Rec (2009)12 and explanatory memorandum, Council of Europe, available at: https://rm.coe.int/16807096bd;
[11] Presumption of Death Act 2013, available at: https://www.legislation.gov.uk/;
[12] When a family member is missing, but their estate is frozen, available at: https://www.bishopandsewell.co.uk/campaigns/presumption-of-death/;
[13] What is the Presumption of Death Act 2013?, available at: https://www.thegazette.co.uk/;
[14] Guardianship (Missing Persons) Act 2017, available at: https://assets.publishing.service.gov.uk/media/5d41a31aed915d09d8945da9/missing-people-code-of-practice.pdf;
[15] Claudia's Law in force: Helping the families of missing people, available at: https://www.kingsleynapley.co.uk/;
[16] Italian Civil Code (Codice Civile Italiano), available at: https://www.wipo.int/wipolex/en/legislation/details/16608;
[17] Ligji nr.03/L-007 për procedurën jokontestimore, G. zyrtare e R Kosovës/Prishtinë: viti IV / nr. 45 / 12 Janar 2009, available at: https://anjf.rks-gov.net/desk/inc/media/F56C5806-4597-416E-BE0D-91CF451E92C2.pdf.

MODELING RISK STRATEGY FORMATION: THE ROLE OF MANAGERIAL EXPERIENCE AND BUSINESS CHARACTERISTICS

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Abstract: The research examines the modeling of risk management strategies in small and medium-sized enterprises (SMEs) in Kosovo, with a specific motivation on the role of managerial experience and business features. The data were collected through an online survey conducted across the entire territory of Kosovo during the period September–October 2024. The examination employs an econometric approach via Ordinary Least Squares to discover the associations among the dependent variable, risk strategy, and a set of independent variables, including managers' experience, unexpected risks, applied strategies, gender, and business size. The results reveal that unexpected risks have a statistically important and positive influence on the formulation of risk strategies, suggesting that SMEs tend to react more proactively when exposed to unforeseen threats. On the other hand, the application of existing strategies, gender, and business size display a statistically significant harmful interplay with the risk strategies, indicating that SMEs with structured risk strategies may resist further adaptation, and that gender dynamics influence strategic decisions. Meanwhile, managerial experience does not demonstrate a statistically important consequence in this model, highlighting that traditional assumptions about their influence may not hold in the Kosovar SME context. These discoveries contribute to the growing literature on SME risk management in emerging economies and underscore the importance of contextual and behavioral factors in shaping effective risk strategies.

Keywords: Risk strategies, manager's experience, unexpected risk.

1. Introduction

Small and medium-sized enterprises (SMEs), according to various discussions and reports developed in both national and international forums, represent a fundamental pillar of economic development and job creation, especially in developing countries such as Kosovo. Beyond managing daily operations, one of the core responsibilities of SME owners or managers is formulating and implementing strategic decisions that ensure long-term financial sustainability and prosperity. As highlighted by Cepel *et al.* (2018), the strategic decision-making process in SMEs constitutes a key determinant of their success in an increasingly complex business environment. In practice, most of the important decisions taken within these enterprises are made under conditions of uncertainty and exposure to various risks. Such risks can be either financial, operational, legal, or even technological aspects, and usually are not easily identified at an earlier phase of investment project development. Risk, in this sense, is an unavoidable and at the same time an ordinary part of every business that is willing to evolve or expand its business. Kwaik, Sweis, Allan, and Sweis (2023) note that, in instances where such risks are not managed in a systemic manner, they can become manifested and affect the overall life cycle of a certain project or strategy in adverse ways.

As markets are globalizing and the acceleration process of digitalization, SMEs are realizing the importance of proactive and effective risk management. In this respect, the integration of risk management strategies has turned out to be a more and more popular practice that prevents and minimizes the negative outcomes that occur as a result of exposure to the internal and external hazards. As stated by Wegner *et al.* (2017), the perception of risk management among SMEs is increasingly becoming more widespread, but it is a developing field, especially in constrained resource settings. A recent empirical analysis conducted in Kosovo, which combined a survey of 55 businesses, through the regression analysis, and qualitative insights, has revealed significant findings that confirm the relevance of risk management in Kosovar SMEs. According to Mehmeti (2025), approximately 78.2% of surveyed enterprises reported a substantial reduction in risk exposure following the adoption of risk management, while 83.6% stated that their financial performance had significantly improved. These

outcomes also correspond with the international scholarship, which has revealed the connection between risk management approaches and such benefits as growing revenue stability, superior market value, and decreased earnings volatility (Yordanova, 2024; Chlodnicka & Zimon, 2020; Psarska *et al.* 2019).

Nevertheless, in the Kosovar setting, the efficiency of the developed risk management strategies is mediated by a number of pivotal considerations. To begin with, 62.9 percent of the surveyed businesses mentioned the inability (because of the lack of managerial capacity and financial resources) to develop and elaborate risk management systems as a significant challenge (Mehmeti, 2025). Additionally, the knowledge and strategic competencies of managers in terms of risk identification, assessment, and action are quite large in general, irrespective of dealing with a large or informally organized company, particularly in terms of structured businesses (University of Portsmouth, online study, 2023). Conversely, in the larger businesses or businesses in the regulated markets, on the other hand, are more likely to display a greater volume of risk management strategies and, as a result, apply risk strategies. Against this background that the overall aim of this research is to both academically and econometrically evaluate the consequences of several factors, i.e., managerial experience, unexpected risks, how risk strategies are implemented, gender of the manager, and the business size on framing and implementation of risk management strategies in the SMEs operating in Kosovo. This methodology will play a critical role as it relates to comprehending the internal aspects that support or fail to support the capacity of an SME to establish feasible risk management contexts.

To complete this objective, an experiential research study was conducted involving 234 respondents from all municipalities of Kosovo. With the aim of attaining this goal, research was carried out empirically, using 234 respondents representing all municipalities of Kosovo. These participants represented a diverse range of enterprise sizes, sectors of activity, and levels of managerial experience. The questionnaire constructed for this study included measurable variables such as managerial experience (in years), types of risks encountered in the past three years, risk management approaches employed, and the influence

of firm size on internal management structures. These data were analyzed under the econometric interplay, which required the use of the Chi-square hypothesis testing on risk strategy, principal component analysis, and linear regression analysis. These methods aimed to identify the meaningful association between independent variables and results with regard to the development of risk strategies. The research is not only serving the academic field of literature on risk management in SMEs but also has great implications for policymakers, supporting institutions, and the business itself. Particularly, it prescribes the following interventions about capacity building, managerial education, and the creation of specific risk management instruments that could be applied to the situation of a small and vulnerable economy, such as the circumstances of Kosovo.

2. Literature review

Given some level of economic uncertainty, as well as the swift technological changes of today, there is a need to have a risk management strategy as part of the sustainability and success of SMEs. Risks, as noted by Ullah *et al*. (2021), are unpredictable occurrences that may have a constructive or undesirable impact on the achievement or non-achievement of the objectives of a business. Given this, risk management strategies are of paramount importance to put in place the right response mechanisms and continuity of operations of a business in unexpected situations. The recent literature highlights that the COVID-19 pandemic has imposed immediate repercussions on the operational and financial areas of SMEs, due to which there is a determination of the survival strategies, especially in the field of financial management and marketing (Ahmad *et al*. 2020). On a larger scale, Belas *et al.* (2023) claim that the process of risk management in SMEs is dictated by a range of factors, including the specificities of a country, industry, and personal traits of the manager, his or her experience, and even his or her gender. These studies justify the need to formulate the risk strategies that are based on the internal and external traits of SMEs.

2.1 Managerial experience

Another important parameter that can affect the creation of risk strategies is managerial experience. The researchers like

de Araujo Lima *et al.* (2020) and Mayr *et al*. (2021) direct that the experience their managers gain in the course of handling management processes enhances risk prediction and reaction capabilities. Experienced managers have higher probabilities of coming up with sound and informed risk sets of guidelines. Moreover, research by Sun *et al.* (2023) and Cao *et al.* (2024) insists on the importance of international managerial experience in increasing risk-taking behavior associated with the development-based strategy and research and development (R&D) investments. The experience with high-level management systems may bring expertise, which leads to risk-taking strategies that help in the growth of value for the firm.

H_1: Managerial experience has a significant positive association with the application of effective risk management strategies in SMEs.

2.2 Unexpected risks

Unexpected risks are a constant threat to SMEs given the fact that the resources available are limited and the flexibility as well. According to Hayur and Khalas (2020), there are two types of risks, internal and external risks, whereas Yordanova (2024) discusses the role of managerial competencies that can be used to address such crises. Dealing with the unexpected risks is not only about pre-determined strategies: one should also have good real-time managerial skills. According to the findings of Ansyari (2024), the effect of the unpredictable risk on the strategic decision-making of SMEs is profound and defines the character of performed strategies.

H_2: Unexpected risks have adverse impacts on the design of sustainable risk management strategies in SMEs.

2.3 Applied strategies

The existence and development of SMEs depend on the selection of particular strategies to mitigate risks. Benjamin et al. (2024) point out the necessity of employing innovative technologies and sustainable policy to minimize the risks, specifically, the ones related to the sphere of cybersecurity. It is also crucial to rely on innovation-based, adaptive, and responsive

strategies to create organizational resilience.

H_3: Applied risk strategies have a constructive effect on the success of risk management in SMEs.

2.4 Gender

The recent research on gender versus risk management indicates that males and females have varying motives in regard to risk-taking. Research conducted by Kariuki (2023) shows that there is a negative interplay between risk-taking behavior and gender diversity on a board in insurance companies. The same outcome can also be used in the SME situation, where female-based enterprises can be more conservative in their risk management finance patterns.

H_4: Gender has a negative influence on risk management in SMEs.

2.5 Business size

Business size is a crucial parameter in defining the capacity of SMEs to withstand impacts and effective risk management options. According to the works by Crovini *et al*. (2021) and Karas & Reznyakova (2021), smaller companies particularly face the risk of failure because of the lack of resources and the inability to address risks in the long-term perspective.

H_5: Business size has a positive influence on risk management strategies in SMEs.

The examination of the literature displays that the risk strategies in SMEs practice are a multi-faceted process depending on different internal and external factors, such as manager experience, the nature of risk, methods of strategy adoption, and also manager gender and business size. The formulated hypotheses give a logical groundwork for empirical examinations and provide a basis for enhancing future research in this area.

3. Research Methodology

3.1 Data sample

To ensure the comprehensiveness and validity of the research, as well as the verification of the proposed hypotheses, the study relies on data collected through an online questionnaire conducted during September and October 2024. A total of 318 questionnaires were initially received. Nevertheless, after a clean screening process, 234 responses showed the needed conditions that could be analyzed further. The questionnaire was in three major parts. The demographic questions with respect to gender, region, size of business, and sector of activity were covered in the first part. The second part concerned the knowledge and managerial experience of the SME owners or managers. The last part consisted of questions that were based on their ideas as to how to understand and apply risk management strategies. A five-point Likert scale was adopted in framing the questions on risk management to obtain the levels of agreement or frequency. The simple random method of sampling was applied to the selection of the sample drawn in seven regions of Kosovo, namely Pristina, Mitrovica, Peja, Prizren, Gjilan, Ferizaj, and Gjakova. The reason to rely on this approach was to include every participant in the likelihood of inclusion in the study, as a guarantee of a greater representative type of data. The adopted methodological design is a mixed-methods strategy. First, descriptive analysis with initial tests was carried out in order to find out the properties of the data. Thereafter, the Chi-squared test of independence and the multiple linear regression test were conducted in order to test its hypotheses with an aim of testing how the variables were related to each other.

In addition, a Principal Component Analysis (PCA) was performed to identify the components with eigenvalues greater than one, thereby determining which parameters held the most explanatory power for inclusion in the final analysis. Altogether, statistical tests and analyses were performed using the econometric software package Stata version 17.0.

3.2 Model

The application of the OLS technique in this study is essential for understanding the impact of both internal and external factors on risk management strategies among SMEs in Kosovo. Initially, the Chi-squared test of independence was employed to assess the relationships between categorical variables, thereby facilitating the identification of statistically significant associations between demographic characteristics and risk strategies (McHugh, 2013). Thereafter, principal component analysis (PCA) was used in order to minimize the dimensionality of the data, in addition to the maximum important latent components that indexed related variables. The eigenvalues above one and the Scree Plot were used to justify the application of PCA (Jolliffe & Cadima, 2016). Finally, OLS regression was utilized to estimate the linear effect of managerial experience, unexpected risks, applied strategies, gender, and business size on risk strategy formulation. OLS remains a classical and widely accepted method for analyzing causal relationships when the dependent variable is continuous and the model does not suffer from severe issues of heteroskedasticity or multicollinearity (Wooldridge, 2019).

Consequently, the overall formula of the model in our specific instance is:

$$Y_{it} = Y_{it-1} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon_i$$

Wherever: Y_{it}- is the dependent variable for component *i* at time *t*, $X_1 - X_5$- are coefficients of independent variables, and, ε_i- is the error term. Applied to the factors in this investigation, the model is stated as follows:

$$\begin{aligned} &\text{Risk strategies}_i \\ &= \beta_1(\text{Managerial experiences}_i) \\ &+ \beta_2(\text{Unexpected risks}_i) \\ &+ \beta_3(\text{Applied strategies}_i) + \beta_4(\text{Gender}_i) \\ &+ \beta_4(\text{Business size}_i) + \varepsilon_{it} \end{aligned}$$

3.3 Findings and discussion

The descriptive statistics used in the research are based on the data gathered on 234 SMEs in Kosovo. The mean score of

Risk strategies is 2.11 and the standard deviation (SD) a 0.57, which means that there is a moderate use of risk management strategies and the scores of this variable are between 1 and 3. *Managerial experience* has a low SD (0.49) and mean (1.55), which indicates that most managers do not have a great deal of professional experience. *Unexpected risks* have a mean of 2.30 and a relatively large standard deviation (1.16), indicative that a firm would be exposed to different levels of uncertainty. Meanwhile, *Applied strategies* present a mean of 1.58 and a considerable dispersion (0.85), indicating heterogeneous approaches to risk management. The variable *Gender* shows a mean value of 1.15, pointing to a dominance of male managers in leadership positions. Lastly, *Business Size* has a mean value of 1.35, confirming that the majority of the sample consists of small enterprises.

Table 1. Descriptive statistics

Description	Obs	Mean	S.D.	Min	Max
Risk strategi	234	2.11	0.57	1.00	3.00

es					
Manager's experience	234	1.55	0.49	1.00	2.00
Unexpected risks	234	2.30	1.16	1.00	5.00
Appl	234	1.582	0.85	1.00	4.00

ied					
Strategies					
Gender	234	1.15	0.36	1.00	2.00
Business size	234	1.35	0.60	1.00	3.00

Source: Author's calculations

These data provide a critical foundation for the inferential analyses that follow. Overall, the descriptive statistics reveal several key elements for further examination: low levels of managerial experience and implemented strategies, inconsistent exposure to unexpected risks, a lack of gender diversity, and the predominance of small-sized enterprises. The combination of those factors characterizes a profile of SMEs that may be

considered relatively risk-prone, with slight internal ability to process risk systematically. This underscores the existence of special measures, including training, systematic methods, and institutional directives that guide the building of risk management capabilities of SMEs in Kosovo.

The outcomes presented in Table 2 for the Chi-square (χ^2) test indicate a statistically significant association between risk strategies and several independent variables included in the examination. Explicitly, the p-values for unexpected risks (p = 0.000), applied strategies (p = 0.000), gender (p = 0.000), and business size (p = 0.029) are all below the 5% significance threshold, signifying the rejection of the null hypothesis and confirmation of the alternative hypothesis. This points toward that these variables are statistically related to the choice of risk strategy.

Table 2. Chi-Square test hypothesis of risk strategy

Variables	Pearson chi2(2)	ρ-value	Confirmation or rejecti

			on of the hypothesis
Manager's experience	2.6320	0.2668	$H_o \rightarrow$ rejected
Un	2	0.	H_a

expected risks	9.076	0.000	→ confirmed
Applied strategies	28.9186	0.000	H_a → confirmed
Gender	28.9186	0.000	H_a → confir

			medH
Business size	7.109	0.029	$_{a}\rightarrow$ confirmed

Source: Author's calculations

According to Wooldridge (2020), the Chi-square test is one of the classical methods for testing the independence between two discrete variables in exploratory data analysis. Similarly, Gujarati and Porter (2021) emphasize that when data are categorical, the Chi-square independence test is an effective tool for identifying associations between nominal or ordinal variables in preliminary statistical assessments. Conversely, for managerial experience, with a p-value of 0.268, there is insufficient evidence to reject the null hypothesis, indicating no statistically significant association.

The outcomes of the VIF breakdown in Table 3 denote that there is no evidence of multicollinearity among the independent variables entered into the analysis. VIF values of all the factors are close to 1, with the mean VIF being 1.03, which is less than the usually accepted number of 5 (Gujarati & Porter, 2021).

Table 3. Vector inflation analysis

Variables	VIF	1/VI

		F
Manager's experience	1.04	0.969
Unexpected risks	1.04	0.964
Business size	1.04	0.965
Gender	1.03	0.973
Applied strategies	1.01	0.990

		75
Mean VIF	**1.03**	

Source: Author's calculations

According to the evidence provided by Wooldridge (2020), a VIF value lower than 10 is normally regarded as not problematic; nevertheless, a lower value nearer to 1 would be an optimal independence of the predictors. Based on this, therefore, these results support the argument that the explanatory variables incorporated in the regression exercise do not display undesirable multicollinearity effects, and therefore, coefficient estimates in the model can be regarded to be stable and reliable.

Table 4 presents the main results of the principal component analysis (PCA), which was used to assess and subsequently reduce the dimensionality of the data by transforming the original variables into independent components that retain most of the information.

Table 4. Principal component analysis

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp 1	1.379	0.171	0.230	0.230

	8	4	0	0
C	1			0
o	.	0	0	.
m	2	.	.	4
p	0	1	2	3
	8	5	0	1
2	5	6	1	4
		1	4	
C		0		
o	1	.	0	0
m	.	1	.	.
p	0	8	1	6
	5	0	7	0
3	2	1	5	6
	8		4	8
C				
o	0	0	0	0
m	.	.	.	.
p	8	0	1	7
	7	8	4	5
4	2	6	5	2
	3	3	4	2
C		0		
o	0	.	0	0
m	.	0	.	.
p	7	8	1	8
	8	5	3	8
5	6	0	1	3
	0		0	2
C		-		
o	0		0	1
m	.		.	.
p	7		1	0
	0		1	0
6	1		6	0
	0		8	0

Source: Author's calculations

The eigenvalues for components 1 through 3 are above 1, which is a common criterion (Kaiser's criterion) for selecting significant components in the analysis. The combined proportion of the components (components 1, 2, and 3) is 0.6068 (and this volume describes about 60.68% of the total variance), which

means that a rather significant part of the information contained in the dataset can be generalized in these plotted lower dimensions. Clusters 4 and 5 have eigenvalues that are less than 1, indicating that they have less contribution in explaining the variance, but when combined with the first three together, they cover more than 88 percent of the variance, which is rated high in the explanation of variance in PC analysis. The sixth component is less than 1, and it is commonly not interpreted as it carries little information relative to that of the whole.

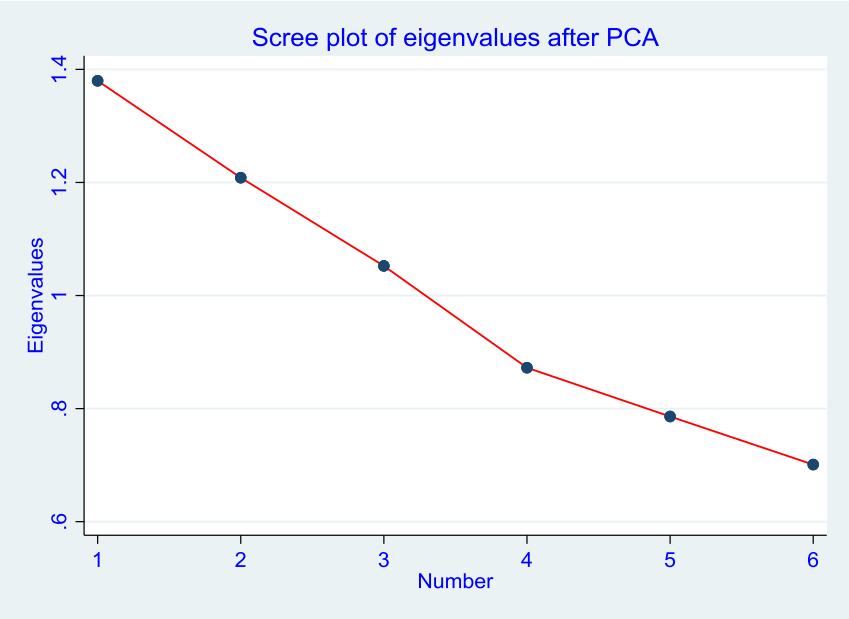

Figure 1: Scree plot
Source: Author compilation

The presented graph is a scree plot that visualizes the eigenvalues after applying Principal Component Analysis (PCA). This plot helps to visually determine the optimal number of components to retain in the analysis and, at the same time, supports the previously discussed findings. The scree plot, as shown in Figure 1, indicates a steep decrease in eigenvalues at the third component in comparison to the results in Table 4, in which components 1, 2, and 3 had eigenvalues that are greater than 1 (i.e., 1.38, 1.21, and 1.05, respectively). This plays the role of a graphic guide to follow the support that Kaiser Criterion, or perhaps the idea to keep simply the components with eigenvalue above 1. The decrease is sharper than before the so-called elbow point at component 3, now, pointing to the idea that components

4 to 6 are introducing comparatively insignificant new material in the context of this work, and components 4 to 6 can be deemed as less critical to the analysis.

Based on the previously discussed assessments, it can be concluded that the data are sufficiently stable and appropriate for further treatment through regression analysis. Therefore, before proceeding with the interpretation of the regression coefficients, it is academically advisable to first evaluate the robustness of the applied approach through several diagnostic tests. It was established that the coefficient of determination is R^2 = 0.5929, which translates into 59. 3 percent of the variance in the risk strategies is embodied by the explanatory variables that were entered into the survey instrument that was administered. This means that the model has an average capability of explanation. The F-test has also given a significant value of 0.000 due to the obtained F value of 4.6700, which has made all variables in the model significant as they are of significant interest to the research. The results indicate that the model is quite specific and statistically balanced. As to the issue of heteroskedasticity, the Breusch-Pagan test gives a p-value = 0.2255, highly above the expected statistical measure of $\alpha = 0.05$. This indicates that heteroskedasticity is not proven in the model and, therefore, the assumption of homoskedasticity is not being contravened. Lastly, to determine the existence of serial correlation, the Durbin-Watson test was used. The test was 2.4137, and it is acceptable between 1.5 and 2.5; hence, the result is considered insignificant autocorrelation in the residuals. On the whole, these diagnostic outcomes confirm the stability and soundness of the regression model.

Table 5. Regression estimation

	OLS	
	β	ρ ≥ [z]
Mana	0	

ger's exper ience	. 0 3 5 0	0 . 6 3 5
Unex pecte d risks	0 . 0 1 5 6	0 . 0 1 9
Appli ed strate gies	- 0 . 1 5 0 9	0 . 0 0 0
Gend er	- 0 . 2 4 2 3	0 . 0 1 6
Busi ness size	- 0 . 0 9 3 7	0 . 0 2 2
Cons _	2 . 6 7	0 . 0 0 0

	28	
Observation	234	
R^2	0.59292	
F-test	4.67000	0.0000
X^2-heteroscedascity	1.47000	0.2255
Durbin-Watson	(6, 234)	2.4137

Source: Author's calculations

Given the outcomes exposed in Table 5, the value of the coefficient of the variable managerial experience is $\beta = 0.0350$ with a ρ-value = 0.635. Since the ρ-value is larger than the generally accepted level of significance (0.05), we have taken it that the managerial experience cannot be said to have a statistically significant influence, whether positive or negative, on the implementation of risk strategy amongst SMEs in Kosovo. The hypothesis H_1 is, therefore, rejected because the results do

not support the original concept of the study. This outcome is contrary to most of the previous empirical research, which tends to point out the importance of managerial experience in the determination of good risk management practices.

In contrast, the variable unexpected risks exhibit a positive and statistically significant effect on risk strategies, with $\beta = 0.0156$ and $\rho = 0.019$. Holding all other factors constant (ceteris paribus), a one-unit increase in perceived unexpected risks is associated with an increase of 0.0156 units in the application of risk strategies. Hence, the hypothesis H_2 can be accepted. Our outcomes are in line with Ansyari (2024), who points out that unexpected risks are sometimes desirable outcomes when handled using suitable strategic decisions. Along the same line, Yordanova (2024) emphasizes that managerial competencies are critical in responding to such unpredictable challenges in the most effective way possible. The modification in applied strategies is highly significant, with a negative association with the risk strategies. Unbiased as the applied strategies to manage risk, as the coefficient of the regression is $\beta = -0.1509$ and the ρ-value is 0.000, which gives a 99.9 percent confidence level. This predicts that a unit decrease in implementation of applied strategies will create a drop in effectiveness of risk strategies by 0.1509 units. Consequently, an alternative version of hypothesis H_3 stands out. The outcomes correspond to the work by Benjamin *et al.* (2024), who have confidence that SMEs will have to employ clearly outlined strategies, especially those that will utilize innovative technologies, as a way to deal effectively with risk and enhance long-term resilience.

Regarding gender diversity, the analysis reveals a statistically significant negative impact on risk strategies, as shown by a coefficient of $\beta = -0.2423$. This indicates that increases in the gender variable are associated with a corresponding decrease in the application of risk strategies. Hence, alternative hypothesis H_4 is confirmed. This outcome aligns with that of Kariuki (2023), who establishes an adverse interaction between gender diversity and taking risks within insurance. This trend could be applied to SMEs, and they would have more conservative approaches to financial risk management when it comes to female-led enterprises. Lastly, business size harms the risk strategies with a 90 percent confidence level, a

coefficient of β = -0.0937, and a ρ-value of 0.022. It implies that the larger the size of the business, the less risk strategies are employed by 0.0937 units. In that way, the alternative hypothesis H5 is also supported. Such discoveries can be compared to those of Crovini *et al.* (2021) and Karas & Reznyakova (2021), who reveal that smaller organizations are especially susceptible because of the shortage of resources and organizational difficulties in dealing with long-term risks.

4. Conclusion

The main objective of this research was to evaluate the influence of specific business-related characteristics associated with risk on the implementation of risk strategies among SMEs in Kosovo. This valuation was grounded in the perceptions of SME managers or owners, collected through a structured questionnaire. A total of 234 valid responses were obtained during the survey period, which covered the entire territory of Kosovo and ensured equal representation across key sectors, namely manufacturing, trade, and services. The research applied a comprehensive methodological approach, employing a series of statistical tests with the overarching aim of fulfilling the research objectives. Finally, a linear regression model was employed to test the hypothesized associations. The econometric analysis revealed that unexpected risks have a statistically significant and positive effect on the application of risk strategies by SMEs. Conversely, applied strategies, gender, and business size also showed significant associations with the dependent variable, but with differing directional effects. A surprising finding was the non-significant influence of managerial experience, which challenges much of the existing literature that emphasizes its centrality in risk management. This outcome suggests that the managerial structures of many SMEs in Kosovo may lack sufficient knowledge regarding risk management methods and may not actively try to find training or capacity-building opportunities to bridge these knowledge gaps.

From a scientific and practical standpoint, this research offers valuable insights that can serve as a guide for SME leadership and policymakers alike. It highlights the need for institutional support in strengthening managerial competencies and for the creation of legal frameworks that provide sound risk

management practices within the SME sector. Nevertheless, the research acknowledges certain limitations, primarily the sample size of 234 questionnaires, which, while sufficient for the current analysis, may constrain the generality of the discoveries. Future research is encouraged to expand the sample size and geographical scope, apply alternative econometric techniques for robustness, and incorporate specific questions related to the techniques and tools used in risk management. Such extensions would deepen the understanding of risk strategy formation and provide more actionable recommendations for SME development and resilience.

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INSTITUTIONAL AND ECONOMIC DETERMINANTS OF EXPORTS: EVIDENCE FROM WESTERN BALKAN COUNTRIES

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Abstract: The interplay among the institutional quality, regulatory environment, and performance in exports is growing in interest in the transition economies like those of the Western Balkans. The competitiveness in exports depends not only on the economic indicators in countries but also on the institutional outlines and effectiveness of regulation. This research examines the main institutional and economic influences of export performance in the Western Balkans from 2017 to 2024. Particularly, it examines the effectiveness of the regulatory trade barriers, judicial independence, contract enforcement, and GDP on export-to-GDP. The research follows the dynamic aspect of the behavior of exports and averts the endogeneity problem that is characteristic of panel data using the Generalized Method of Moments (GMM). The results imply significant continuity of the export performance. Regulatory trade barriers have adverse influences on exports, meaning that the degree of regulation has the capability to limit the trade action. Conversely, judicial independence positively relates to export growth, which underlines the relevance of a credible and independent legal system. The result of contract enforcement does not provide an important influence, implying that there is the possibility of enforcement mechanisms not being enough to increase the amount of export. There is a robust positive association, on the other hand, between GDP and exports, supporting the notion that there is a connection between economic growth and trade. These results underline the significance of institutional innovations and regulatory quality to develop export-based expansion policy in the Western Balkans.

Keywords: Export, institutional factors, macroeconomic, GMM.

1. Introduction

In the cases of fragile and emerging economies, like the Western Balkans, exports are a very important source of long-term economic growth, competitiveness, and structural adjustment. The aspiration of the region to be more integrated in the world markets and the European Union requires not only macroeconomic stability but also the reinforcement of the institutional frameworks, which facilitate international trade. Nonetheless, gradual reforms have led to the persistence of structural weaknesses in many Western Balkan countries, hindering export performance, such as poor and weak rule of law, lack of an effective mechanism to enforce contracts, excessive regulatory burden, and the existence of low levels of productive capacity (World Bank, 2024). More conventional export performance models have dedicated most of their attention to macroeconomic variables on the provision side, i.e., those related to growth in GDP, exchange rates, or inflation (Durguti *et al.* 2020). However, there is an increasing number of studies that focus attention on the crucial position occupied by institutional quality in the trade process, especially in the fields of developing and emerging markets (D'Ingiullo *et al.* 2023; Helpman, 2020). When the institutions are efficient and predictable, transaction costs are reduced, investor confidence is increased, and the conditions necessary to protect the legality of contracts essential to export expansion are provided. Conversely, bad institutional frameworks lead to uncertainty and risk, which is a deterrent to all forms of trade activities, including domestic and foreign.

The fundamental purpose of the research is to put forward a detailed and thorough investigation into the nature of the effect of the quality of institutions on export performance dynamics in the setting of the Western Balkan countries. Particularly, the research is interested in the empirical analysis of the influence of the four most prominent elements of institutional and macroeconomic quality on export performance, which are the regulatory barriers to trade, judicial independence, the enforcement of contracts, and gross domestic product. The reason why these variables are chosen is that they are well-

proven on the theoretical and practical levels and have a robust influence on the overall business climate and the process of international trade integration. The objective of the analysis is to establish how functional institutions and regulatory structures contribute to the export activity, either as hindering or enhancing variables in the international trade development theory in the modern context. To accomplish this goal, the research uses annual data in the range of 2017 to 2024, which is provided by such highly trustworthy sources as the World Bank database on macroeconomic data and the Fraser Institute, which gains the trust of the scientists due to the indicators on institutional quality (Freiser Institute, 2024; Gwartney *et al.* 2023). They are standardized and cross-nationally comparable data sources, thus securing a strong base for the econometric analysis to be conducted far ahead.

The research is motivated by the assumptions that institutional performance, in addition to economic prowess, has a monumental influence on the capacity of such nations to participate in the international markets competently. Some of the key research questions are as follows:

- *How does export capacity depend upon regulatory barriers?*
- *Does a robust trade outcome come about with a more independent and functioning judiciary?*
- *How important is the enforcement of contracts to the regional exporters?*
- *The nature of the relationship between the growth of GDP and export performance is.*

Nevertheless, it is decisive to point out that the countries, which are the focus of this analysis, still have a number of structural challenges, where institutional aspects also play a distinguished role. These issues are characterized by the problems of an ineffective effort of the court system, low rates of contract enforcement, an absence of institutional autonomy, and the existence of regulatory restrictions on economic and trade activity. Besides weakening the business environment in general, such inefficiencies in institutions impair the complete penetration of these nations into the global trade cycles, a phenomenon that negatively influences their export performance as well as their capacity to achieve the European-challenged standards of

integration. However, there are many barriers stated by the governments or public and private institutions. Economic stakeholders are protected from the unanticipated effects of unexpected policy changes, non-tariff barriers, corruption, and preferential treatment of certain companies or sectors by the stronger oversight mechanisms that democracy inherently provides over government power and the economy (Bjørnskov and Schröder, 2023). Well-functioning legal institutions may act as a hedge against contract violations and further claims, indirectly protecting exporting enterprises from immediate losses, even when some of the barriers offered by particular market participants may appear dubious or nonexistent (Yu *et al.* 2015).

Based on the above argument, this research is expected to make a significant contribution on a variety of fronts. *First*, it attempts to contribute to the already existing academic literature, especially by filling gaps applicable to the countries to be studied. *Second*, the employment of dynamic econometric methods that are different and unique from the traditional static models provides a better comprehension of the connections between the institutional factors and export performance. *Finally*, the study aims at creating policy-relevant information that would be valuable input to decision-making units as well as to institutional stakeholders who are involved in making economic and institutional reform.

2. Objective of the Study

The objective of this study is to examine the institutional and economic determinants of export performance in the Western Balkan countries, focusing on the effects of regulatory trade barriers, judicial independence, contract enforcement, and GDP. By using a dynamic panel data approach with the Generalized Method of Moments (GMM), the study aims to identify how institutional quality and economic factors interact to influence export growth and provide empirical evidence to support policy development for enhancing export competitiveness in the region.

3. Literature review

Most of the previous analysis on export performance revolved around macroeconomic factors, including growth in GDP, exchange rate, inflation, and import and export openness. Nevertheless, literature in the past ten years has enlarged on institutional aspects, especially the quality of institutions that play a role in determining trade outcomes. Institutional quality is the robustness of the rules of governance, the rule of law, regulations, judicial independence, and their enforcement. All of these institutional factors are also coming to be seen as essential to macroeconomic fundamentals. Regulatory trade barriers, for instance, have emerged as a dominant theme in current trade literature. Jakšić, Erjavec, and Cota (2021) focused on analyzing Central, Eastern, and Southeastern European economies that shifted their tightly controlled systems into full EU membership. They argue that with the panel data analysis that even after a policy reform to encourage free movement, there exists regulatory restraint on the movement of people, goods, and capital. Such jurisdictions also enjoy the decline in the non-tariff barriers since this development is associated with the improved performance of exports and increased capital mobility (Jakšić *et al.* 2021). Their results point to the fact that elements of institutional legacies of planned economies may last longer and slow down the effects of integration unless there are efforts to liberalize regulations.

Munemo (2022) extended this analysis to examine the data collected on 60 countries covering the period 2006 and 2014 that were evaluated using previous indicators to understand the influence of the regulation-driven obstacles on export entrepreneurship. Using econometric modeling on entry rates and export survival, Munemo revealed that unfavorable regulatory environments, especially in countries with low governance quality, greatly decrease the chances of exporters who can enter and surviving in the foreign markets. The impression is further emphasized in countries where either the rule of law was weak, the political environment unstable, or it was inefficient in bureaucracies, a factor that can help to support the institution strength aspect that supports in instituting exports (Munemo, 2022). Services trade is important in the digital age. Wang, Zhang, and Zhu (2024) examined 39 economies between 2010 and 2019 in terms of how the effects of regulatory trade barriers

influence the export of digital services. They were identified with the constructive association between well-managed and balanced regulatory frameworks and efficiency in exporting digital services. This means that regulations that are not as limiting as others are, nor as open as others are, can facilitate innovation as well as export competitiveness in the digital industries by dampening uncertainty as well as ensuring easy cross-border digital trading.

Supplementary institutional characteristics that are currently coming under the empirical spotlight beyond the regulatory barriers include judicial independence. A quasi-natural experiment by Gao and Kong (2024) considering the circuit courts in China concluded that regions, which had the judicial function enhanced, showed much greater exports, technical complexity, and integration. As revealed by the study, a more independent judiciary facilitates integration of the markets, restrains protectionist distortions as well, and enhances export quality (Gao & Kong, 2024). In line with international evidence, Wang, Wang, and Li. (2014) compared the performances of provincial exports to those regions with distinct quality of the judiciary. They noted that an increase in the impartiality and efficiency of judicial systems in the appropriate legal jurisdictions where firms operate is associated with increased exportation and entry into more developed markets, implying that legal credibility and effectiveness related to legal enforcement directly affect the behaviour of exportation.

Associated with the judicial quality is the contract enforcement, which has been seen as important to international trade. Recently, Ongjin (2010) directly exhibited that an economy with a well-developed structure of contract enforcement expressed by legal transparency, quickness of responsibility, and trustworthiness of enforcement will likely lead to better results on the export effectiveness because of the improved security of contracts and lessening of hazard. D'Ingiullo *et al.* (2023) employed a mixed econometric method involving shapes of OLS, fixed-effects, and System-GMM models on the study of the Italian provincial data, observed that effective legal systems lower the costs of transactions and uncertainty, enhance capital stock growth and firm productivity,

which completely lead to enhanced export performance. Additional empirical evidence can be attributed to the study by Gani (2018), which conducted a panel data analysis of the indicators of contract enforcement, time of contract enforcement, type of contract enforcement, and the number of procedural actions. Wholly three indicators have registered significant negative interplay with the levels of trade, indicating that delays, excessive bureaucracy, and expensive mechanisms of contract enforcement are significant barriers to exports in the developing countries.

On a broader scale, Markakkaran and Sridharan (2022) used the System-GMM on the comprehensive panel of 101 countries (1995-2019) and examined a two-way connection between export and economic growth. Their outcome confirmed the constructive role of exports' contribution to the GDP via the spillover phenomenon and economies of scale, in particular in the developing economies (also those of the Western Balkans). Durguti *et al.* (2021) explicitly studied the Western Balkan economies and found the constructive dependency of the GDP and the volume of exports, which proves the role of economic growth in serving the export capacity. It was also noted that export diversification is attained by the economies with stable growth patterns (Hesse, 2023). Diversification makes them less vulnerable to shocks. Nonetheless, Moradi and Augustin (2025) warn that the direction of causality is a debatable question-whereas a group of scholars claims that exports are a growth driver, there is another group that states that exports are growing more easily due to a more significant GDP improvement connected with increased effectiveness and capacity. Overall, this academic evidence highlights the following pillars of institutions as crucially important to export performance: a) regulatory trade barriers which increase the cost of compliance and market access unless wisely handled, b) judicial independence which generates trust, enforcement of fairness and establishes incentives in the eyes of the exporters, and c) contract enforcement which decreases transactional risk discouraging opportunism and leads to stable trade relations.

Institutional quality is complemented by macroeconomic strength, as the growth in the GDP increases the capacity of production and export absorption. The combination of these

dimensions indicates that the key to the successful performance of exports in transition and emerging economies is the soundness of the economy and its institutions. The developed institutional macroeconomic approach defines a sophisticated value in studying the trade dynamics in the Western Balkans, a region of both developing governance and reflective trade policies. It therefore encourages the empirical study with the help of dynamic panel methodologies, e.g., System-GMM, which is able to accommodate the persistence, endogeneity, and heterogeneity across time and countries.

3. Research Methodology

To provide a justified and methodologically adequate answer to the research questions outlined in the introduction, this research has elaborated an analytical approach that will most suitably correspond to the active character of the topic being researched. The methodological strategy is expected to provide an empirical evaluation of the influence of institutional quality and gross domestic product (GDP) on the dynamics of the volume of exports for the Western Balkan countries. The research employs balanced panel data for the period between 2017 and 2024, which is sufficient to exactly look at structural and cross-temporal relationships like the chosen criteria. The selection of this particular timeframe will be determined by the availability of data since some of the countries being analyzed could not find complete and comparable data for longer periods. Consequently, the time range 2017 to 2024 can be taken as a sensible trade-off between the extent of the period and the quality of data. In the present research, the data have been used that were collected in two of the most respectable and credible institutions, such as the World Bank and Fraser Institute, owing to their trustworthiness and scientific objectivity.

The sources are very common in academic literature and offer standardized and internationally comparable indicators. More explicitly, the data on export and GDP were collected by the World Bank and presented as a percentage of GDP, so the analysis could be carried out on the comparative impressions of the variables on the trade performance of the countries under investigation. On the other hand, the Fraser Institute had

provided indicators of institutional quality, which were calculated on a scale of 0 to 10, with the lowest performer score of 0 and the highest performer being 10; these indicators were used as an indicator of the state of institutional quality. This measurement method of standardization makes the results easy to interpret and compare the results among the countries. It should be stressed that such an approach and the choice of the data sources have already been legitimized by very credible research on the economy and institutional development obverse, such as the works of Alidemaj *et al.* (2025), Gao and Kong (2024), and Durguti *et al.* (2021). Such an appeal to the institutionalized literature strengthens the scientific trustworthiness of the given research and also forms a sound basis for the subsequent econometric analysis.

3.1 Model

In order to meet the research purpose and sufficiently cover the dynamic nature of the data used in the research, the econometric method of the Generalized Method of Moments (GMM) is employed in the research. According to the argument presented by many studies in the past, such a methodology is superior to traditional statistical models in most dimensions of econometric analysis (Arellano & Bond, 1991). In this regard, the choice of GMM does not happen by chance but is scientifically grounded to pursue multidimensional benefits that are discussed below based on the position of the authors, like Klinac (2023) and Ercegovac et al. (2024). First, this method is more applicable to panel data that are dynamic, and in this case, the data was used, whereas this method does not presume that the time series is in a long-run equilibrium. This is a major strength on its part, and most of the economic variables used do not meet the classic conditions of being stationary. Second, the changes measured by the GMM are evaluated by taking the first difference of an individual dependent variable (exports), therefore, permitting us to analyze its relative performance to the past and apply it to comprehend the time-based developments within the inquiries. Third, the GMM methodology enables the use of internal instruments to capture individual effects, provided that these instruments are defined appropriately and consistently (Hansen, 1982). Finally, this approach offers advanced treatment of econometric issues such as endogeneity, heteroskedasticity,

and serial autocorrelation, which frequently characterize economic data (Arellano & Bover, 1995; Blundell & Bond, 1998). In light of these methodological advantages and based on both theoretical and practical considerations, this study adopts the GMM approach as the most appropriate strategy for the proposed empirical analysis. Accordingly, the general form of the model in our specific case is:

$$Y_{it} = \alpha_0 Y_{it-1} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \eta_i + \varepsilon_{it}$$

Wherever: Y_{it}- is the dependent variable for component *i* at time *t*, $\alpha_0 Y_{it-1}$- is the lagged dependent variable, $X_1 - X_5$- are coefficients of independent variables, η_i- signifies country-specific unobserved effects, and, ε_{it}- is the error term. Applied to the variables in this study, the model is stated as follows:

$$\begin{aligned} &\text{EXP\_GDP}_{i,t} \\ &= \alpha_0 \text{EXP\_GDP}_{i,t-1} \\ &+ \beta_1 (\text{Regulatory trade barriers}_{i,t}) \\ &+ \beta_2 (\text{Judicial independence}_{i,t}) \\ &+ \beta_3 (\text{Constract enforcement}_{i,t}) \\ &+ \beta_4 (\text{Gross domestic product}_{i,t}) + \eta_i + \varepsilon_{it} \end{aligned}$$

3.2 Results discussion

The summary of the descriptive statistics is presented in Table 1, where for each variable the minimum and maximum values, the arithmetic mean, and the standard deviation are reported. The initial data indicate that exports, expressed as a percentage of GDP, reached a minimum value of 21.69%, while the maximum recorded value was 73.98%.

Table 1. Descriptive statistics

Description	Obs	Mean	S. D.	Min	Max

n					
Exp_GDP	48	44.957	13.167	21.695	73.958
Regulatory trade barriers	48	7.601	0.961	5.890	8.900
Judicial	48	4.708	0.788	3.640	6.230

independence					
Contract enforcement	48	3.437	0.390	2.850	4.830
Gross domestic	48	3.199	4.359	-15.306	13.043

e
s
t
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c

p
r
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d
u
c
t
s

Source: Author's calculations

The overall average export is estimated to be 44.95%, with a standard deviation of 13.16%, which indicates a moderate variability of the Western Balkan countries in the course of the study. Respectively to regulatory trade barrier, they have a mean value of 7.60 points, varying between the lowest of 5.89 and the highest of 8.90, indicating that a lot differentiates between countries in the approaches to regulation. The lowest mean scores were recorded in indicators of the institutional environment, namely judicial independence and contract enforcement, whereby average scores stood at 4.71 and 3.43, respectively, and indicated that there continued to be problems around the functioning of institutions of the rule of law. Lastly, the gross domestic product produced on average at a rate of 3.19% during the period under observation, with this value being the standard deviation of 4.35%. The arithmetic reported extremes of this variable extend to a negative extreme value, -15.31% representing instances of acute contraction of the economy, whereas the highest reported value is 13.04 % representing periods of spirited economic growth.

Table 2 presents the correlation coefficients among the five key variables included in the analytical model: exports as a percentage of GDP, regulatory trade barriers, judicial independence, contract enforcement, and gross domestic product.

Table 2. Correlation analysis

Variables	Exp_GDP	Regulatory barriers	Judicial independence	Contracts enforcement	Gross domestic product
Exp_GDP	1.000				
Regulatory	-0.221	1.000			

trade barriers				
Judicial independence	-0.198	0.563	1.000	
Contra	-0.408	-0.19	0.206	1.000

cts		2			
enforcements					
Gross	0.1382	0.0405	0.0092	0.1005	1.0000
domestic products					

Source: Author's calculations

Firstly, a negative correlation is observed between

exports and regulatory trade barriers (-0.221), suggesting that an increase in regulatory barriers tends to be associated with a decline in export levels. This result aligns with theoretical expectations, as trade barriers generally pose obstacles to international trade. Additionally, exports are negatively correlated with judicial independence (-0.198) and especially with contract enforcement (-0.408), which may indicate a fragile institutional environment that undermines trust and efficiency in international transactions. Conversely, the correlation between exports and GDP is positive (0.138), although relatively weak, implying a modest but positive association between economic growth and export performance. The strong positive correlation between regulatory trade barriers and judicial independence (0.563) is particularly noteworthy, potentially reflecting a complex relationship between institutional quality and market regulation. Based on the reported results, it is observed that none of the correlation coefficients exceed 0.80, which provides a robust indication that the data does not suffer from multicollinearity (Gujarati & Porter, 2009).

Table 3. Vector inflation analysis

Variables	VIF	1/VIF
Judicial independence	1.73	0.578437
Regulatory trade	1.72	0.581

barriers		2.135
Contracts enforcements	1.23	0.81101014
GDP growth	1.02	0.98290909
Mean VIF	**1.42**	

Source: Author's calculations

Reported statistics in Table 3 demonstrate that the values of VIF are below the critical point of 10, with a mean value being 1.42. This implies that serious issues about the multicollinearity of the independent variables are absent, and the model is recommendable to be advanced econometrically. The results support the methodological guidelines agreed under consideration, Wooldridge (2016), as he states the necessity to control the level of multicollinearity to guarantee reliable measures.

To confirm the validity of the estimated empirical results, the study carried out a sequence of diagnostic tests before and after the regression estimation, widely known as robustness checks.

Table 4. Regression estimation

	GMM standard		***GMM robust***	
	β	ρ ≥ [z]	β	ρ ≥ [z]
EXP_GDP L1.	0.758	0.000	0.758	0.000
Regulatory trade ba	-4.652	0.089	-4.652	0.093

r r i e r s				
J u d i c i a l i n d e p e n d e n c e	1 1 . 2 7 7	0 . 0 0 1	1 1 . 2 7 7	0 . 0 0 9
C o n t r a c t e n f o r c	- 0 . 0 4 1	0 . 9 8 7	- 0 . 0 4 1	0 . 9 8 8

ements				
Gross domestic product_cons	0.9511 -8.6422	0.0000 0.6711	0.9511 -8.6422	0.0000 0.6887
Observer	48		48	

variation				
Heteroskedasticity	0.3711	0.5422		
Wald chi2	257.25	0.0000	293.33	0.0000
Sargan	36.5585	0.0081		

test				
AR1			-1.664	0.0096
AR2			-0.491	0.623

Source: Author's calculations

Initially, the heteroskedasticity test revealed a coefficient of 0.371 and a p-value of 0.542, which means that there is no problem of heteroskedasticity since the p-value is not less than the standard level of 0.05 as recommended by Greene (2012). Moreover, the chi-square Wald test (χ^2 = 257.25; ρ = 0.000) indicated that all the coefficients used in the model are statistically significant, and this fact proves the effectiveness of the variables utilized (Wooldridge, 2010; Greene, 2012). In order to test the suitability of the instruments, as well as the non-endogeneity, the Sargan test was executed, and it produced the value of 36.585 with the p-value of 0.081. These outcomes do not reject the null hypothesis, implying that the instruments are valid and properly specified in the model. Considering by post-estimation diagnostics, there were small deviations from the standard, and these findings led to the conclusion that there is model stability. Furthermore, $AR_{(1)}$ and $AR_{(2)}$ tests were used to analyze whether there was serial correlation or not. It is important to note that first-order autocorrelation was identified, which can be considered a frequent finding in models involving GMM, but this problem was no longer observed at the second order, which is consistent with the econometric arguments provided by Arellano & Bond (1991) and Roodman (2009).

The outcomes of the econometric model obtained and

exposed in Table 4 represent strong evidence about the influence of the chosen institutional and macroeconomic factors on the performance of exports of the Western Balkan countries between 2017 and 2024. On the one hand, the variable regulatory trade barriers display a negative and statistically substantial coefficient at a 10 percent level (ß = -4.65; 0 < 0.1). It means that a 1 unit decrease in the quality of the trade-regulating environment corresponds with a loss in export levels of 4.65 percentage points on average. The outcome supports the existing literature, especially the one provided by Jakšic et al. (2021), regarding the idea of a considerable regulatory burden in the economies of emerging countries with low institutional quality, which precludes trade openness and (further) exports. In a similar vein, Munemo (2022) carries the argument to the effect that the existence of undesirable regulatory policies in an environment of fragile governance has a significant, adverse impact on export performance.

Second, the judicial independence variable has a very high and statistically significant positive impact on exports, with a coefficient of 11.277 and a p-value of 0.001. This indicates that a unit increase in judicial independence has an average increase of 11.27 percentage points of an increase in exports. This outcome is consistent with the results conducted by Gao and Kong (2024) in their provision of a comparative study on different provinces within China, one of their points being that the ones with a more independent and efficient judicial system record better export performance. Along the same line of explanations, Wang, Wang, and Li (2014) identify the significance of effective judicial institutions in facilitating international trade activity. Third, the contract enforcement variable possesses a negative value concerning exports. However, such an effect is not significant, implying that there is no measurable effect in the specification of the current model.

Lastly, there is the gross domestic product that exhibits a positive and highly significant consequence on the exports (p = 0.95; p < 0.01). This displays that a 1 percent increase in GDP is associated with about a 0.95 percent increase in exports, which further evidences the fact that domestic economic growth has positive effects on the export capability. This can be inferred using relevant literature, according to which previous studies

confirmed a positive interplay among economic activity and export performance (Moradi & Augustin, 2025; Markakkaran & Sridharan, 2022; Durguti et al., 2021).

4. Conclusion

The study contains a robust empirical test in the domain of the determination of export performance of the Western Balkan countries in the time frame 2017 to 2024 based on institutional and macroeconomic factors. Employing the GMM to address the issue of endogeneity and dynamic effects based on annual panel data obtained at the World Bank and Fraser Institute, the analysis shows that the institutional quality, as well as the macroeconomic fundamentals, are very important determinants of export dynamics in the region. The discoveries support the negative influence of the regulatory trade barriers on exports as being statistically significant. Explicitly, an improvement in the quality of the trade-regulatory environment is linked with an increase in export performance, and it confirms the impression that overregulation and excessive administration are variable obstacles to trade openness, especially in developing and transition economies where the institutional capacity is low. Additionally, judicial independence demonstrates a high, positive, and statistically significant effect on exports. Its results imply that some enhancement in the independence and effectiveness of the judiciary system may bring more legal certainty, upholding of property rights, and elements of contractual performance essential in building a stable and appealing trade climate. Contract enforcement also has a negative coefficient but is not deemed to be statistically significant in the model, and this is a pointer that better enforcement of contracts alone will not help much unless in the broader context of other institutional reforms. Conversely, gross domestic product has a strong and extremely significant positive influence on exports, a fact that reiterates that inward economic development and the capacity to produce at a certain level are fundamental in improving trade capacity and global competitiveness.

The policy implications of these discoveries can be significant to policymakers in the Western Balkans. In trade development strategies, it should be the priority to strengthen the institutional framework, especially in the domain of regulatory

governance as well as judicial independence. The effect of reforms to simplify regulation, cut bureaucratic red tape, and improve judicial fairness and efficiency may directly and quantifiably influence export performance. As well, measures that enhance domestic economic growth, including investment in infrastructure, supporting the growth of productive industries, are certain to indirectly enhance export potential. As future research, one could be interested in investigating the interaction effect of the institutional variables and macroeconomic indicators, and the influence of regional integration schemes, including CEFTA or EU pre-accession processes, on these export processes. Adding the firm-level or sectoral data may even enhance the comprehension of the process of interpreting the quality of institutions into the export performance at the microeconomic level. In addition, carrying out the analysis further than 2024 with new data will enable the researcher to analyze the post-pandemic and geopolitical impacts on regional trade performance.

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THE USE OF ARTIFICIAL INTELLIGENCE IN HIGH SCHOOLS IN NORTH MACEDONIA

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Abstract

Artificial Intelligence (AI) is increasingly reshaping educational practices worldwide, particularly at the secondary education level. This paper examines the current and emerging role of AI in high schools in North Macedonia, focusing on patterns of use, institutional readiness, ethical challenges, and long-term implications for teaching and learning. Drawing on national digital readiness assessments, policy documents, and qualitative insights from teachers and classroom practices, the study highlights a growing gap between rapid student adoption of AI tools and the slower institutional and regulatory response. While AI offers strong potential to support personalized learning, inclusion, and pedagogical innovation, its unregulated use raises concerns related to academic integrity, unequal access, and skill dependency. Aligning the analysis with UNESCO's human-centered and ethical AI frameworks, the paper proposes policy-oriented and pedagogical recommendations aimed at ensuring that AI enhances rather than undermines the educational quality and equity in North Macedonia's secondary education system.

Keywords: Artificial Intelligence; Secondary Education; High Schools; Digital Readiness; Education Policy; AI Literacy; North Macedonia

1. Introduction

Artificial Intelligence (AI) has transitioned over the past decade from a niche technological concept into a pervasive socio-technical phenomenon that increasingly shapes everyday life, work, and learning. In education, AI-powered systems now support tasks ranging from automated feedback and adaptive learning platforms to generative tools capable of producing text, translations, and problem-solving explanations.[58] Secondary education, and particularly high schools, represents one of the most sensitive and consequential environments for AI adoption, as students at this level are still developing core cognitive, ethical, and social competencies.[59]

In North Macedonia, the diffusion of AI tools among high-school students has accelerated markedly since the early 2020s. The expansion of digital learning during and after the COVID-19 pandemic normalized the use of online platforms, digital resources, and algorithmic assistance. As a result, students increasingly rely on AI-based tools for writing assignments, summarizing learning materials, translating between Macedonian, Albanian, and English, and solving mathematical or scientific problems. This rapid adoption has occurred largely outside formal curricular structures and without explicit institutional regulation.

At the same time, national and international assessments reveal that digital readiness within the Macedonian education system remains uneven. While some urban schools benefit from relatively stable infrastructure and digitally confident staff, many rural and peripheral schools face persistent challenges related to connectivity, device availability, and teacher training.[60] These structural disparities raise concerns that AI integration may amplify existing educational inequalities rather than mitigate them.

Despite North Macedonia's broader commitment to digital transformation reflected in national ICT strategies and e-government reforms there is currently no comprehensive policy framework that

[58] Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Boston, MA: Center for Curriculum Redesign.
[59] Selwyn, N. (2019). *Should robots replace teachers? AI and the future of education*. Cambridge: Polity Press.
[60] van Dijk, J. A. G. M. (2020). *The digital divide*. Cambridge: Polity Press.

specifically addresses the use of AI in secondary education.[61] Teachers often navigate AI-related issues independently, relying on personal judgment rather than standardized guidelines. This situation creates uncertainty regarding academic integrity, assessment fairness, and pedagogical responsibility.

Against this background, this paper seeks to provide a realistic and context-sensitive analysis of how AI is currently used in high schools in North Macedonia, what challenges this use creates, and how national education policy can respond in a way that is ethical, equitable, and pedagogically sound. By situating local practices within international frameworks, particularly UNESCO's human-centered AI principles, the study aims to contribute to ongoing academic and policy debates on AI governance in education.

2. Background and Policy Context

2.1 Digital Transformation in North Macedonia

Over the past decade, North Macedonia has undertaken a series of reforms aimed at strengthening its digital infrastructure, improving public administration efficiency, and aligning national policies with European Union digital standards. These efforts are reflected in multiple strategic documents that emphasize information and communication technologies (ICT), innovation, and digital skills development as key drivers of economic and social progress.[62]

Within the education sector, digital transformation has primarily focused on basic digital literacy, the introduction of electronic registers, online learning platforms, and limited forms of blended learning. While these initiatives have contributed to increased familiarity with digital tools, they have not been designed with advanced technologies such as Artificial Intelligence in mind. As a result, the institutional capacity to manage AI-driven change remains underdeveloped.[63]

[61] Ministry of Information Society and Administration. (2021). Draft National ICT Strategy 2021–2025. Skopje: MISA.
[62] Ministry for Digital Transformation. (2023). SMART/MK 2030 – ICT Development Strategy. Skopje: MDT.
[63] Williamson, B., & Hogan, A. (2020). *Commercialisation and privatisation in/of education in the context of COVID-19*. Education International Research.

Secondary education is particularly affected by this gap. High schools operate under centralized curricular frameworks that leave limited room for rapid pedagogical experimentation. Furthermore, investment in school-level digital infrastructure varies significantly across regions, reinforcing long-standing urban–rural divides. These contextual factors shape how, and to what extent, AI tools are accessed and used by students and teachers.

2.2 International Frameworks on AI and Education

At the international level, UNESCO has emerged as a central normative actor in the governance of AI in education.[64] Its policy guidance emphasizes that AI systems should be designed and deployed in ways that respect human rights, promote inclusion, and preserve the central role of teachers in the learning process. Rather than replacing educators, AI is framed as a supportive tool that can enhance pedagogical effectiveness when used responsibly.

UNESCO's frameworks also stress the importance of transparency, accountability, and critical AI literacy. Learners are encouraged not only to use AI tools, but to understand their limitations, potential biases, and ethical implications. These principles are particularly relevant for secondary education, where students are forming long-term learning habits and civic values.

For countries such as North Macedonia, international frameworks provide both guidance and legitimacy. Given limited domestic expertise in AI governance, policy alignment with UNESCO recommendations offers a practical pathway for developing national strategies that are internationally credible while locally adaptable.

3. Research Objectives and Questions

The main objective of this study is to analyze how Artificial Intelligence is currently used in high schools in North Macedonia and to assess the readiness of the educational system to manage its impact responsibly.

The research addresses the following questions:

[64] UNESCO. (2021). AI and education: Guidance for policy-makers. Paris: UNESCO.

1. How do high-school students and teachers in North Macedonia currently use AI tools?

2. What institutional and infrastructural factors shape AI adoption in secondary education?

3. What challenges does AI pose for academic integrity, assessment, and skill development?

4. How can national policies and school-level practices be aligned with ethical AI frameworks?

4. Methodology

This study employs a qualitative and policy-analytic research design. Rather than relying on large-scale surveys, it focuses on contextual understanding through document analysis and experiential insights.

4.1 Data Sources

The research draws on:

- National policy documents and digital readiness reports.
- International guidelines on AI and education.
- Informal classroom observations conducted during 2024–2025.
- Semi-structured interviews with secondary-school teachers.
- Comparative analysis with international trends in AI-supported education.

4.2 Analytical Approach

The collected materials were analyzed thematically, with particular attention to patterns of AI usage, perceived benefits, ethical concerns, and institutional gaps. This approach allows for a realistic and human-centered interpretation of how AI is experienced in everyday school settings.

5. Patterns of AI Use Among Students

The findings indicate that the use of Artificial Intelligence among high-school students in North Macedonia is both widespread and

normalized, yet largely informal and unsupervised. Students typically begin using AI tools independently, often influenced by peers, social media platforms, and online tutorials rather than through structured instruction within the school environment. As a result, AI use develops organically, shaped more by convenience and perceived efficiency than by pedagogical intent.

In practical terms, students most frequently employ AI tools for summarizing textbooks and lecture notes, generating drafts for essays and seminar papers, translating learning materials between Macedonian, Albanian, and English, and obtaining step-by-step solutions for mathematical, scientific, and technical problems. For many students, AI functions as a personalized on-demand tutor, available outside school hours and without formal constraints.[65]

This pattern of use reflects broader shifts in student learning behavior. Faced with dense curricula, time pressure, and high expectations for performance, students often view AI as a coping mechanism rather than a substitute for learning. Interviews and classroom observations suggest that students frequently justify AI use as a means of understanding content more quickly or overcoming language barriers, particularly in subjects with complex terminology.[66]

However, the largely uncritical adoption of AI tools raises important concerns. Many students demonstrate limited awareness of how AI systems generate responses, the possibility of factual inaccuracies, or the presence of algorithmic bias. Verification of AI-generated information is inconsistent, and students rarely distinguish between AI-assisted drafting and fully automated content production. This lack of critical engagement underscores the absence of formal AI literacy education within the secondary school curriculum.

Furthermore, patterns of AI use are closely linked to students' digital confidence and access to technology. Students with personal laptops, stable internet connections, and prior exposure to digital tools are more likely to exploit advanced AI functionalities. In contrast, students with limited access often rely on basic features or avoid AI altogether, reinforcing existing educational disparities.

[65]Zawacki-Richter, O., Bond, M., Marin, V. I., & Gouverneur, F. (2019). *Systematic review of research on artificial intelligence applications in higher education – Where are the educators?* International Journal of Educational Technology in Higher Education, 16(39), 1–27.

[66] Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., & Kasneci, G. (2023).

6. Teachers' Perspectives and Professional Challenges

Teachers' perspectives on the growing presence of Artificial Intelligence in high schools reveal a complex mix of openness, uncertainty, and concern. While many educators acknowledge that AI tools are already embedded in students' learning practices, they often feel insufficiently prepared to respond to this transformation in a pedagogically sound manner.

A central issue identified by teachers is the lack of professional training related to AI. Most educators report that their formal training and continuous professional development focus primarily on basic digital competencies, such as the use of learning management systems or presentation software. Advanced topics such as generative AI, algorithmic decision-making, or ethical AI use are largely absent from existing training programs. As a result, teachers frequently rely on self-learning or informal experimentation, leading to uneven levels of competence across schools and subjects.

Academic integrity represents one of the most pressing professional challenges. Teachers increasingly encounter assignments that display linguistic sophistication or structural coherence inconsistent with students' prior performance. The difficulty of verifying authorship undermines confidence in traditional assessment methods and places educators in a position of suspicion rather than pedagogical support. Many teachers expressed concern that excessive policing of AI use could damage trust between teachers and students.

In the absence of institutional guidance, teachers adopt diverse coping strategies. Some attempt to restrict AI use entirely, emphasizing handwritten or in-class work. Others tacitly allow AI-assisted work while focusing assessment on oral explanations or classroom participation. This diversity of approaches reflects professional autonomy, but it also contributes to inconsistency and uncertainty within the education system.

Despite these challenges, teachers also recognize AI's potential benefits. Educators note that AI tools could support lesson planning, generate differentiated materials, assist students with special educational needs, and facilitate multilingual instruction. However, realizing these benefits requires structured support, clear ethical standards, and institutional recognition of AI as a pedagogical issue rather than a disciplinary problem.

7. Digital Inequality and Access Gaps

Digital inequality remains a fundamental structural challenge shaping how Artificial Intelligence is accessed and used within North Macedonian high schools. Although national strategies emphasize digital inclusion, the practical realities of school-level infrastructure reveal persistent disparities across regions and socio-economic contexts.[67]

Urban schools, particularly those in Skopje and larger municipalities, are more likely to benefit from stable internet connectivity, updated computer equipment, and greater exposure to digital innovation. Teachers in these settings often report higher confidence in experimenting with new technologies and greater institutional support. In contrast, rural and peripheral schools frequently operate with outdated hardware, limited numbers of shared devices, and unreliable internet access. These constraints significantly reduce opportunities for meaningful AI integration.

Digital inequality also intersects with socio-economic factors at the household level. Students from higher-income families are more likely to own personal laptops or smartphones capable of running advanced AI applications, while others rely on shared or school-provided devices. This uneven access affects not only the frequency of AI use but also the depth and quality of engagement with digital tools.

The risk posed by these inequalities is the emergence of a stratified education system in which AI-enhanced learning becomes a privilege rather than a public good. Students in well-resourced environments may develop advanced digital and AI-related competencies, while others fall further behind. Such outcomes contradict the principles of equity and equal opportunity that underpin public education policy.

Addressing digital inequality therefore requires more than infrastructure investment. It demands coordinated policies that integrate device provision, connectivity improvement, teacher training, and curricular innovation. Without such measures, AI integration may inadvertently reinforce existing educational and social divides rather than reduce them.

8. Ethical and Pedagogical Implications

[67] AmCham North Macedonia. (2024). Digitalization Position Paper. Skopje: AmCham.

The rapid and largely unregulated use of Artificial Intelligence in high schools raises a complex set of ethical and pedagogical questions that extend beyond technical considerations. These issues are particularly sensitive in secondary education, where students are still developing intellectual autonomy, moral judgment, and academic identity.

From an ethical perspective, data privacy and informed consent represent major concerns. Many AI-based educational tools operate through cloud-based platforms that collect user inputs to improve system performance. In most cases, students are unaware of how their data are stored, processed, or potentially reused. This lack of transparency conflicts with UNESCO's emphasis on protecting learners' rights and ensuring that AI systems respect privacy and human dignity.[68]

Another ethical challenge relates to authorship and intellectual honesty. When students submit AI-generated or AI-assisted work without clear disclosure, the boundaries between original learning and automated output become blurred. Teachers interviewed during this study emphasized that the issue is not simply rule-breaking, but the gradual erosion of students' sense of ownership over their learning process. UNESCO explicitly warns that uncritical reliance on generative AI may undermine authentic learning and assessment integrity if not accompanied by clear ethical guidelines.[69]

Pedagogically, the impact of AI is similarly ambivalent. On the one hand, AI tools can support differentiated instruction by adapting explanations to students' individual learning pace, language proficiency, and prior knowledge. This is particularly relevant in linguistically diverse classrooms in North Macedonia, where AI-based translation and explanation tools can reduce learning barriers and support inclusion.

On the other hand, excessive dependence on AI risks weakening core competencies such as critical thinking, independent writing, and problem-solving. When students rely on AI-generated answers rather than engaging in cognitive struggle, learning may become superficial and instrumental. This concern is echoed in international research, which highlights the danger of skill atrophy when AI substitutes rather

[68] UNESCO. (2025). AI and education: Protecting the rights of learners. Paris: UNESCO.
[69] Miao, F., & Holmes, W. (2023). Guidance for generative AI in education and research. Paris: UNESCO.

than supports human reasoning.

Balancing these ethical and pedagogical dimensions requires a deliberate shift from reactive control toward proactive guidance. Rather than banning AI tools, schools need frameworks that promote responsible use, transparency, and reflection. Embedding ethical discussion about AI into classroom practice can transform AI from a shortcut into a learning object itself, aligning technology use with educational values.

9. Discussion

The findings of this study reveal a clear mismatch between the rapid diffusion of Artificial Intelligence in everyday learning practices and the slower institutional response within the secondary education system in North Macedonia. Students have already integrated AI tools into their academic routines, while teachers and policymakers continue to operate within frameworks designed for pre-AI educational environments.

This gap reflects a broader pattern observed in digital transformation processes, where technological innovation advances more quickly than governance structures. In the absence of national AI-in-education policies, responsibility is effectively shifted to individual schools and teachers, resulting in fragmented and inconsistent practices. Such decentralization may foster experimentation, but it also risks deepening inequalities and undermining educational coherence.

From a policy perspective, the Macedonian case illustrates the limitations of digital strategies that focus primarily on infrastructure and basic digital literacy. While access to devices and connectivity is necessary, it is insufficient for managing the systemic implications of AI. Advanced digital skills, ethical literacy, and pedagogical innovation must be treated as equally important components of digital readiness.[70]

Pedagogically, the findings suggest that traditional assessment models are increasingly misaligned with contemporary learning realities. Written homework and take-home essays are particularly vulnerable to AI-assisted production, raising questions about their continued validity as measures of student competence. International guidance increasingly

[70] United Nations Development Programme. (2024). Digital Readiness Assessment: North Macedonia. Skopje: UNDP North Macedonia.

recommends diversified assessment approaches, including oral examinations, project-based learning, and in-class tasks, as more resilient alternatives in AI-rich environments.[71]

Importantly, this discussion does not frame AI as an inherently negative force. Rather, the central issue is governance. When integrated within clear ethical boundaries and supported by teacher training, AI can enhance inclusion, personalize learning, and reduce administrative burdens. Without such frameworks, however, AI risks amplifying existing structural weaknesses within the education system.

10. Policy Recommendations

To ensure responsible AI integration in high schools, the following measures are recommended:

1. **National AI-in-Education Strategy:** Develop a dedicated policy aligned with UNESCO principles.
2. **AI Literacy Curriculum:** Introduce structured instruction on AI concepts, limitations, and ethics.
3. **Teacher Training:** Provide continuous professional development focused on pedagogical AI use.
4. **Assessment Reform:** Promote project-based, oral, and in-class assessments.
5. **Equity Measures:** Invest in infrastructure and device access, particularly in rural schools.

11. Conclusion

Artificial Intelligence is no longer a speculative future technology within North Macedonian high schools; it is a present and influential component of students' everyday learning experiences. This study has demonstrated that while AI tools are widely used by students for academic support, institutional readiness and policy guidance remain limited.

[71] UNESCO. (2021). AI and education: Guidance for policy-makers. Paris: UNESCO.

The analysis highlights three interrelated challenges. First, the absence of a national AI-in-education framework leaves teachers without clear standards for ethical and pedagogical decision-making. Second, persistent digital inequalities risk creating uneven access to AI-enhanced learning opportunities. Third, traditional assessment practices are increasingly incompatible with AI-mediated learning environments.

At the same time, the findings underscore the constructive potential of AI when aligned with human-centered educational values. International frameworks emphasize that AI should support but not replace teachers, promote inclusion, and strengthen critical thinking rather than undermine it.[72] For North Macedonia, aligning national policy with these principles represents both a challenge and an opportunity.

Looking forward, future research should extend this qualitative analysis through empirical studies involving students, longitudinal assessment of learning outcomes, and comparative research across the Western Balkans. Such work would contribute to a deeper understanding of how smaller education systems can govern AI responsibly under conditions of limited resources.

In conclusion, the responsible integration of Artificial Intelligence into high school education in North Macedonia depends not on technological capability alone, but on ethical awareness, pedagogical adaptation, and coherent policy design. With timely and inclusive reforms, AI can become a catalyst for educational improvement rather than a source of disruption and inequality.

12. Literature

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[72] Miao, F., & Holmes, W. (2023). Guidance for generative AI in education and research. Paris: UNESCO.

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- Miao, F., & Holmes, W. (2023). Guidance for generative AI in education and research. Paris: UNESCO.

THE IMPACT OF BRAND EQUITY AND BRAND POSITIONING ON THE CONSUMER'S CHOICE: COMPARATIVE ANALYSIS OF HUAWEI AND APPLE ON THE MACEDONIAN MARKET

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ABSTRACT

The holistic perspective of branding, as a long-term strategy, includes a wide set of activities ranging from product innovation to marketing communication. The objective of branding strategy is to create brands that are differentiated from the competition, thereby reducing the number of substitutes in the marketplace. Branding strategies are built on the interdependent frameworks of competitive brand positioning, value chain development, and brand equity management. Competitive brand positioning requires identification of a distinct market space and a cognitive location as perceived by consumers. A competitive position is attained through strong brand recognition, which can be developed by differentiating product attributes such as product features, quality, selection, price, and availability.

This research paper analyzes and elaborates brand management from the perspective of brand equity, brand positioning, and brand image as sources of competitive advantage in terms of consumer choice and customer satisfaction. The topics are elaborated through an extensive literature review and an analysis of key brand performance categories, using the cases of Huawei and Apple as leading international brands.

The conducted quantitative research on a sample of Macedonian respondents shows that brand performance plays a pivotal role in achieving competitive advantage. The obtained results show clear positive correlations between customer satisfaction and built-in quality, timely software updates, video and photo quality, price, and the tendency to purchase a newer model. The results position Apple as a leader over Huawei across all categories, which is further confirmed by market performance indicators.

Keywords: Brand Management, Brand Equity, Brand Positioning, Brand Image, Competitive Advantage, Customer's Choice

1 Introduction

The Branding has existed for centuries as a means of distinguishing the goods of one producer from those of another. Through the creation of names, logos, symbols, and other identifying elements, brands enable firms to establish awareness, reputation, and prominence in the marketplace. In contemporary competitive environments, branding represents far more than a visual identifier; it is a strategic asset that plays a crucial role in shaping consumer perceptions, influencing purchasing behavior, and enhancing business success.

Brands differentiate products that may otherwise appear similar by creating meaningful associations in the minds of consumers. These associations are formed through perceptions of product attributes, performance, quality, values, and emotional connections. As markets become increasingly saturated with comparable offerings, brand awareness and recognition have become essential factors in guiding consumer choice. When consumers are familiar with a brand and perceive it positively, they are more likely to develop loyalty and preference, which in turn contributes to higher market share and long-term competitive advantage (Chi, 2009).

Brand equity represents one of the most significant mechanisms through which brands influence consumer behavior. It reflects the added value that a brand name provides to a product or service and serves as a key tool for capturing consumer attention and facilitating purchase decisions (Bansah, 2015). In markets characterized by minimal product differentiation, strong brand equity reduces perceived risk and simplifies decision-making for consumers. Consequently, companies invest substantial resources in understanding consumer behavior and managing brand-related perceptions, recognizing brands as critical business assets that directly affect customer satisfaction and purchasing decisions (Rindell, 2008).

The concept of brand equity has been widely discussed in the literature. Aaker (1991) defines brand equity as a set of brand assets and liabilities linked to a brand's name and symbol that add to or subtract from the value provided to a firm and its customers. Keller (1993), from a consumer-based perspective, emphasizes the differential effect of brand knowledge on consumer response to marketing activities. From an information economics viewpoint, Erdem and Swait (1998) describe brand equity as the value of a brand as a credible signal of product positioning. Despite differences in perspective, these definitions converge on the idea that brand value is ultimately created through its impact on consumer perceptions and behavior.

Closely related to brand equity is brand positioning, which represents one of the most sensitive and influential elements of brand strategy. Brand positioning refers to the process through which firms seek to establish a distinct and favorable image of their brand in the minds of target consumers. Given the diversity of consumer preferences, perceptions, and values, effective positioning requires a clear understanding of how a

brand differs from competitors and how these differences are communicated. Differentiation through functional, emotional, or psychological attributes enables brands to stand out, shape perceived value, and foster consumer loyalty.

In this context, brand management emerges as a strategic discipline focused on integrating brand equity, brand awareness, and positioning to achieve sustainable competitive advantage. Understanding how these elements influence consumer choice is essential for firms seeking to succeed in highly competitive markets. This study builds on these theoretical foundations by examining brand management through the lenses of brand equity, brand positioning, and brand image, and by exploring their role in shaping consumer behavior and satisfaction.

1.1 Aim, objectives and the research methodology

The aim of this research paper is to examine the brand management process and identify the key factors that contribute to brand differentiation and effective market positioning. The study focuses on two successful international brands, Apple and Huawei, whose brand management practices are analyzed to explore the relationships between brand equity, brand positioning, brand image, competitive advantage, consumer choice, and customer satisfaction.

To assess the positioning and market success of these brands in the Macedonian mobile handset market, a quantitative research approach was employed. The analysis is based on selected brand performance and positioning variables, including built-in quality satisfaction, timely software updates, video and photo quality satisfaction, price satisfaction, and consumers' tendency to upgrade to newer models.

The primary objective of the research is to verify that strong brand equity and appropriate brand positioning significantly influence consumer choice. From a methodological perspective, the study aims to analyze the impact of brand positioning and brand image on competitiveness, market performance, and marketing strategies of Apple and Huawei in the Macedonian market. The research further addresses the importance of focused brand management processes, brand awareness, and brand performance in achieving meaningful points of differentiation and sustainable competitive advantage.

The study is based on secondary data from company reports and relevant brand management literature, complemented by primary quantitative data collected from Macedonian consumers.

2 Brand Equity and Brand Positioning

2.1 Brand Definition

This study confirms that branding represents a strategic process through which firms create differentiation, build brand equity, and influence consumer choice. Strong brand positioning, supported by consistent quality, innovation, and effective marketing

communications, enhances brand recognition, reduces price sensitivity, and contributes to sustainable competitive advantage. The analysis of Apple and Huawei demonstrates that successful brands achieve market leadership by aligning brand equity, positioning, and value delivery with consumer expectations, highlighting the critical role of well-managed branding strategies in long-term business success.

Furthermore, the findings emphasize that consumer perceptions of quality, innovation, and brand reliability play a decisive role in shaping satisfaction and loyalty. The empirical results from the Macedonian market show that brands with clearly defined positioning and strong performance attributes are more likely to achieve superior market outcomes. In this context, Apple's consistent brand strategy demonstrates the effectiveness of long-term brand equity building. Overall, the research underlines that strategic brand management is not only a marketing function but a key driver of competitive performance and market success.

2.2 Brand Management

Nepotism and highly centralized control are key characteristics of man-ruled enterprises, leading to secrecy, randomness, and managerial unpredictability. Huawei reflects this model through strong central oversight, where authority is tightly controlled by top leadership, particularly by its founder Ren Zhengfei. While this structure enables fast decision-making, it raises concerns about long-term organizational sustainability and brand development. Huawei balances centralization with orderly, layered decentralization, allowing incremental adaptation to market demands. The company emphasizes continuous improvement through incremental changes in technology, management processes, and marketing strategies. By responding rapidly to customer feedback, Huawei delivers customized solutions and maintains competitiveness across multiple industries. Huawei has also demonstrated transformational "re-orientation" by proactively investing in new technologies such as LTE and entering the global smartphone market. Strong leadership has positioned Ren Zhengfei as a central change agent driving urgency, learning, and international expansion. Huawei's adoption of global management standards and performance systems supports strategic alignment and continuous improvement. Overall, Huawei's success illustrates how strong leadership, organizational learning, and adaptive change can sustain competitive advantage in a highly dynamic global market.

2.3 Brand Equity - Huawei & Apple

Brand equity is a critical intangible asset that strongly influences consumer purchase intentions and supports firms in international markets. For globally operating companies, strong brand equity enhances both international competitiveness and domestic reputation. Huawei's brand development has been closely supported by the Chinese government through financial, policy, and technological assistance. Government-backed loans, export credit financing, and R&D support played a decisive role in Huawei's early

survival and international expansion. Support for national telecom standards, such as TD-SCDMA, further strengthened Huawei's technological legitimacy. Local government initiatives in Shenzhen also created a favorable innovation-oriented environment for Huawei's growth. Without extensive state protection and policy support, Huawei would likely not have survived intense early competition. Over time, Huawei leveraged this foundation to become the world's largest telecommunications equipment manufacturer. Its brand equity is therefore built on technological capability, state support, and rapid internationalization.

Apple's brand equity, in contrast, is driven primarily by strong financial performance, innovation, and exceptional customer loyalty. Apple became the world's most valuable company, reflecting the strength of its brand and investor confidence. Despite fluctuations in share price, Apple consistently delivered strong revenues, profits, and high returns on equity. The iPhone remains Apple's main revenue driver, supported by premium pricing and high margins. To reduce reliance on hardware sales, Apple has strategically shifted toward a services-based ecosystem. This ecosystem leverages brand loyalty to generate stable, recurring revenue streams. Although declining iPhone unit sales raised investor concerns, higher average selling prices partially offset this trend. Apple's services segment is increasingly important for long-term brand sustainability. Strong share buyback programs and investor support, including from Warren Buffett, further reinforce Apple's brand strength. Overall, Huawei and Apple demonstrate that brand equity can be built through different paths—state-supported technological expansion versus market-driven innovation and loyalty—yet both remain central to long-term competitive advantage.

3 Brand Positioning

3.1 Huawei Brand Positioning

Huawei Technologies is the world's largest provider of telecommunications technologies and China's second-largest privately held corporation. Guided by its vision "To enrich life through communication," Huawei has built a reputation as a highly innovative and fast-growing global technology company. In 2010, Huawei secured 47 major managed services contracts, supporting customers in improving network performance and operational efficiency while reducing costs. The company has actively responded to the digitalization of society, aligning with key industry transitions from voice to data, from pipes to content, from human-to-human to machine-to-machine communication, and from CT to ICT. These transformations position the telecom industry for broadband convergence and further growth opportunities.

By the end of 2010, Huawei had deployed over 80 SingleRAN networks worldwide, including 28 LTE/EPC networks that were commercially launched or under deployment.

The company maintained a market-leading position in optical access and transmission products and experienced rapid growth in the software segment. Huawei's Global Services business expanded steadily, strengthening its role in professional services. Significant growth was also recorded in the operator resale market, particularly in developed economies such as the United States and Japan. Supported by strong technological capabilities, Huawei's radio access business achieved a global market share of approximately 20%.

Huawei showcased its technological leadership at CTIA Wireless 2010 by demonstrating LTE-Advanced technology with record-breaking downlink speeds of up to 1.2 Gb/s. These achievements were recognized with major awards at the LTE World Summit 2010. Huawei's expansion in Europe is exemplified by its rapid growth in the Polish market, where it entered the smartphone segment in 2011. By 2016, Huawei had reached a 20% share of the Polish smartphone market and became the second-largest vendor by value. Poland has since emerged as a key regional market within Central and Eastern Europe and the Nordic region.

Huawei's European operations reflect a clear functional division across research, manufacturing, logistics, sales, and technical support. Research and development activities are concentrated mainly in Western Europe, while manufacturing and logistics are located primarily in Central and Eastern Europe. The company has established an extensive European R&D network, with major centers in cities such as Munich, Milan, and Moscow. Through these investments, Huawei has embedded itself in advanced European innovation systems. This strategic positioning enables Huawei to achieve first-mover advantages and sustain long-term competitiveness in future mobile technology markets.

3.2 Apple Brand Positioning

The modern marketplace exposes consumers to vast amounts of information, making brand positioning essential for creating meaning and differentiation. Positioning focuses not on the product itself but on how consumers perceive the brand, emphasizing its subjective and symbolic value. As a result, brand positioning has become a central strategic tool in marketing and brand management. Apple represents a strong example of effective brand positioning due to its consistent and distinctive strategic approach.

Through corporate and umbrella positioning, Apple has built a powerful brand identity that fosters strong customer loyalty. Its positioning emphasizes innovation, individualism, and lifestyle, allowing consumers to subjectively complete the brand message. Apple also benefits from a strong halo effect, where positive perceptions of one product extend to others within the brand portfolio. The introduction of products such as the iPod played a pivotal role in reinforcing this effect and enabling entry into new markets.

Apple's success demonstrates that brand positioning requires continuous monitoring and adaptation as market conditions evolve. Overall, Apple's sustained competitiveness

highlights brand positioning as a powerful strategy for influencing consumer choice and achieving long-term brand value.

4 Data and Methodology

The empirical research was conducted to analyze the key brand success factors of Apple versus Huawei. The study examined brand satisfaction among Apple and Huawei customers from the perspective of product and brand benefits (quality, timely software updates, multimedia, price, and upselling).

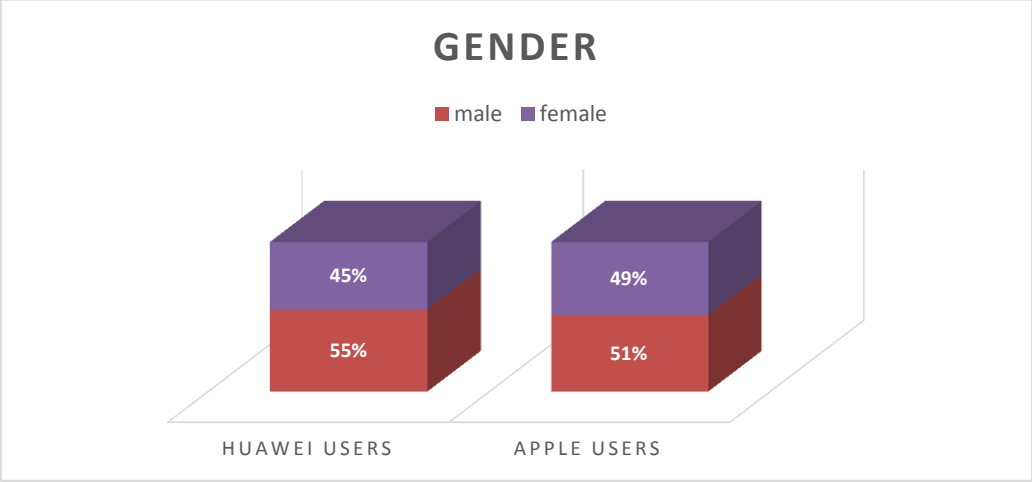
The survey measured the overall satisfaction of Huawei and Apple device users. The claims were divided into five categories, from which five research variables were formed: Built-in Quality Satisfaction, Timely Software Updates Satisfaction, Video and Photo Quality Satisfaction, Price Satisfaction, and Tendency Towards Upgrading to a New Model. Each category was evaluated using a Likert scale from 1 to 10. The research surveyed 80 respondents of both sexes who use Apple and Huawei devices, based on a questionnaire (presented in Appendix 1).

Data were processed using SPSS statistical software, and a t-test was used to determine the differences between the two groups of users (Apple and Huawei). This research is based on a quantitative method and uses correlation analysis to determine the relevance of the phenomena under investigation. For the statistical analysis, a t-test was used to determine the differences between the groups examined.

The survey covered a total of 80 respondents, divided into two groups. The survey was sent to 150 Huawei and Apple users, but responses were received from only 80. The two groups are equal in number, with 40 respondents in each group. The first group consists of users of Huawei devices, while the second group consists of users of Apple devices.

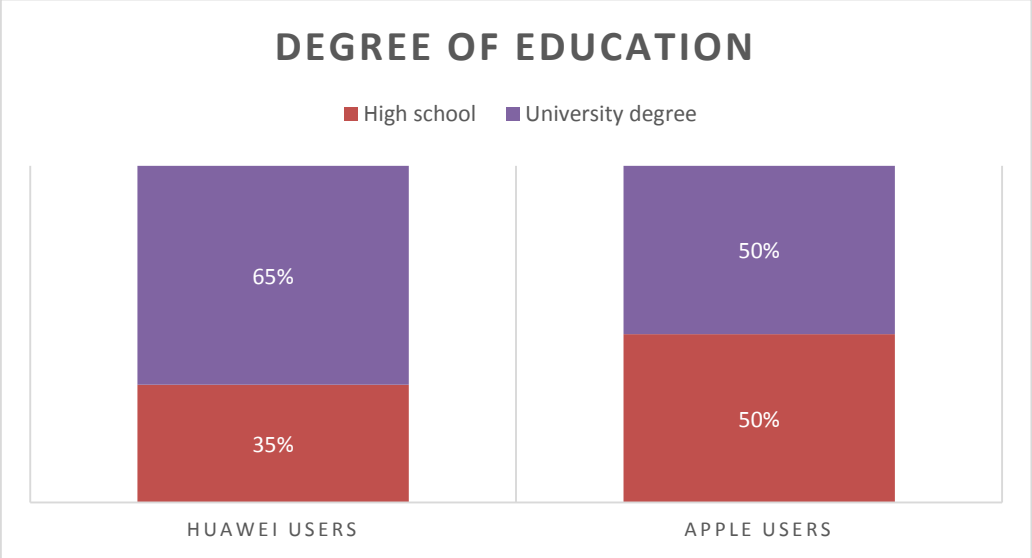
The sample is heterogeneous in terms of gender: among Huawei users, 55% are male and 45% are female; among Apple users, 51% are male and 49% are female, as shown in Graph 1. The degree and type of education are shown in Graph 2.

Graph 1: Gender of Huawei and Apple users in North Macedonia



Source: Author's research

Graph 2: Degree of the education of Huawei and Apple users in North Macedonia



Source: Author's research

The age of the respondents ranged from 18-60 years to an average of 38.5 (± 4 years). The survey was conducted online in January and February 2019, in region of Skopje. The survey was sent to respondents, upon previously requested consent for collection of data and information.

5 Results and Discussion

5.1 Research results of the Huawei users

Table 1 shows the descriptive statistics for the variables: built-in quality satisfaction, timely software satisfaction, video and photo quality satisfaction, price satisfaction and tendency towards upgrade to new model for Huawei users.

Table 1: Descriptive statistics for Huawei users

HUAWEI users	N	Min	Max	M	SD	Skewness	Kurtosis
Built-in quality satisfaction	40	36.0	94.0	65.75	17.43	-0.33	-0.21
Timely software updates satisfaction	40	8	33	20.82	7.94	-0.21	-1.21
Video and photo quality satisfaction	40	16	41	26.12	8.47	-0.04	-1.44
Price satisfaction	40	7	30	18.06	5.54	-0.31	-0.39
Tendency towards upgrading to new model	40	6	59	28.35	18.36	-0.12	-1.47

Source: Prepared by the author using SPSS software.

From the results obtained in Table 1, it can be observed that the arithmetic mean (M) or the average value for respondents regarding Built-in Quality Satisfaction is M = 65.75. Considering the minimum score of 36 and the maximum rating of 94 for Built-in Quality Satisfaction, the findings indicate that the value obtained (M = 65.75) is closer to the maximum score. Therefore, the results suggest that the majority of Huawei device users are more satisfied with the built-in quality. The range of scores for the variable Timely Software Updates Satisfaction among Huawei device users ranges from 8 to 33. The arithmetic mean is M = 20.82, and the standard deviation is $\sigma = 7.94$.

The range of scores for the variable Video and Photo Quality Satisfaction among Huawei device users ranges from 16 to 41. The arithmetic mean is M = 26.12, and the standard deviation is σ = 8.47. The range of scores for the variable Price Satisfaction among Huawei device users ranges from 7 to 30. The arithmetic mean is M = 28.35, and the standard deviation is σ = 18.36.

The range of scores for the variable Tendency Towards Upgrading to a New Model among Huawei device users ranges from 6 to 59. The arithmetic mean is M = 28.35, and the standard deviation is σ = 18.36. Regarding skewness values, all variables exhibit negative skewness, indicating an accumulation of scores toward the higher end of the scale (positively asymmetric distribution). Concerning kurtosis, Table 1 shows negative kurtosis, with values less than 3; therefore, the distribution is leptokurtic.

5.2 Research results of the Appe users

Table 2 shows the descriptive statistics for the variables: built-in quality satisfaction, timely software satisfaction, video and photo quality satisfaction, price satisfaction and tendency towards upgrade to new model for Apple users.

Table 2. Descriptive statistics for Apple users

APPLE users	N	Min	Max	M	SD	Skewness	Kurtosis
Built-in quality satisfaction	**40**	**52.00**	**94.00**	**79.98**	**9.65**	**-1.69**	**3.03**
Timely software updates satisfaction	**40**	**15**	**35**	**29.07**	**4.42**	**-1.57**	**2.50**
Video and photo quality satisfaction	**40**	**14**	**42**	**30.42**	**4.02**	**-1.36**	**7.76**
Price satisfaction	**40**	**3**	**30**	**9.6**	**7.99**	**1.21**	**0.54**

Tendency towards upgrading to new model	**40**	**15**	**60**	**49.9**	**11.37**	**-1.46**	**1.78**

Source: Prepared by the author using SPSS software.

From the results obtained in Table 2, it can be observed that the arithmetic mean (M) or the average value for respondents regarding Built-in Quality Satisfaction is M = 79.98. Considering the minimum score of 40 and the maximum rating of 94 for Built-in Quality Satisfaction, the findings indicate that the value obtained (M = 79.98) is closer to the maximum score. Therefore, the results suggest that the majority of Apple device users have higher satisfaction with the built-in quality.

The range of scores for the variable Timely Software Updates Satisfaction among Apple device users ranges from 15 to 35. The arithmetic mean is M = 29.07, and the standard deviation is σ = 4.42. The range of scores for the variable Video and Photo Quality Satisfaction among Apple device users ranges from 14 to 42. The arithmetic mean is M = 30.42, and the standard deviation is σ = 4.02.

The range of scores for the variable Price Satisfaction among Apple device users ranges from 3 to 30. The arithmetic mean is M = 9.6, and the standard deviation is σ = 7.99. The range of scores for the variable Tendency Towards Upgrading to a New Model among Apple device users ranges from 15 to 60. The arithmetic mean is M = 49.9, and the standard deviation is σ = 11.37.

Regarding skewness, four of the variables show negative skewness, indicating an accumulation of scores toward the higher end of the scale. In the case of Price Satisfaction, there is positive skewness, indicating an accumulation of scores toward the lower end of the scale. In terms of kurtosis, Table 2 shows that the values are around 3, except for Price Satisfaction; therefore, the distribution is leptokurtic.

5.3 Discussion of Results

The results from the research can be interpreted and analyzed based on the significance of difference between Huawei and Apple users.

Table 3 – Significance of the difference for Built-in quality satisfaction between Huawei and Apple users

Group	N	M	SD	Df	F	t	P
HUAWEI – Built-in quality satisfaction	**40**	**65.75**	**17.434**	**78**	**23.155** .000	**-4.515**	**0.000**
APPLE - Built-in quality satisfaction	**40**	**79.98**	**9.654**				

Source: SPSS

Table 3 presents the results of testing the differences between Huawei and Apple users in terms of Built-in Quality Satisfaction. The value obtained for the F-test does not exceed the critical value for F, which means that F is not significant and the t-test can be used. From the table above, we see that Huawei users (M = 65.75) have lower built-in quality satisfaction than Apple users (M = 79.98).

The obtained t-test value is -4.515 and exceeds the critical value at the 0.01 level. With 99% confidence, we can conclude that there is a statistically significant difference; that is, Apple users have higher built-in quality satisfaction than Huawei users.

Table 4. Significance of difference for Timely Software Updates satisfaction between Huawei and Apple users

Group	N	M	SD	Df	F	t	P
HUAWEI - Timely software updates satisfaction	40	20.82	7.94	78	17.387 .000	- 5.737	0.000
APPLE - Timely software updates satisfaction	40	29.07	4.42				

Source: SPSS

Table 4 presents the results of testing the differences between Huawei and Apple users in terms of Timely Software Updates Satisfaction. The value obtained for the F-test does not exceed the critical value for F, which means that F is not significant and the t-test can be used.

From the table above, we see that Huawei users (M = 20.82) have lower Timely Software Updates Satisfaction than Apple users (M = 29.07).

The obtained t-test value is -5.737 and exceeds the critical value at the 0.01 level. With 99% confidence, we can conclude that there is a statistically significant difference; that is, Apple users have higher Timely Software Updates Satisfaction than Huawei users.

Table 5. Significance of difference for Video and Photo Quality satisfaction between Huawei and Apple users

Group	N	M	SD	Df	F	t	P
HUAWEI - Video and photo quality satisfaction	40	26.12	8.47	78	39.793 .000	-2.900	0.005
APPLE - Video and photo quality satisfaction	40	30.42	4.02				

Source: SPSS

Table 5 presents the results of testing the differences between Huawei and Apple users in terms of Video and Photo Quality Satisfaction. The value obtained for the F-test does not exceed the critical value for F, which means that F is not significant and the t-test can be used.

From the table above, we see that Huawei users (M = 26.12) have lower Video and Photo Quality Satisfaction than Apple users (M = 30.42). The obtained t-test value is -2.900 and exceeds the critical value at the 0.05 level. With 95% confidence, we can conclude that there is a statistically significant difference; that is, Apple users have higher Video and Photo Quality Satisfaction than Huawei users.

Table 6. Significance of difference for Price Satisfaction between Huawei and Apple users

Group	N	M	SD	Df	F	t	P
HUAWEI - Price satisfaction	**40**	**18.60**	**5.54**	**78**	**3.409 .069**	**5.849**	**0.000**
APPLE - Price satisfaction	**40**	**9.60**	**7.99**				

Source: SPSS

Table 6 presents the results of testing the differences between Huawei and Apple users in terms of price satisfaction. The value obtained for the F-test does not exceed the critical value for F, which means that F is not significant and the t-test can be used.

From the table above, we see that Huawei users (M = 5.54) have lower price satisfaction than Apple users (M = 7.99). The obtained t-test value is 5.849 and exceeds the critical value at the 0.01 level. With 99% confidence, we can conclude that there is a statistically significant difference; that is, Apple users have higher price satisfaction than Huawei users.

Table 7. Significance of difference for Tendency Towards Upgrading to new model between Huawei and Apple users

Group	N	M	SD	Df	F	t	P
HUAWEI – Tendency towards upgrading to new model	40	28.35	18.36	78	19.013 .000	-6.310	0.000
APPLE – Tendency towards upgrading to new model	40	49.90	11.37				

Source: SPSS

Table 7 presents the results of testing the differences between Huawei and Apple users in terms of the tendency to upgrade to a new model. The value obtained for the F-test does not exceed the critical value for F, which means that F is not significant and the t-test can be used.

From the table above, we see that Huawei users (M = 18.36) have a lower tendency to upgrade to a new model than Apple users (M = 49.90).

The obtained t-test value is -6.310 and exceeds the critical value at the 0.01 level. With 99% confidence, we can conclude that there is a statistically significant difference; that is, Apple users have a higher tendency to upgrade to a new model than Huawei users.

The results of the research show clear positive correlations between customer satisfaction and built-in quality, timely software updates, video and photo quality, price, and the tendency to upgrade to a new model. Apple is the clear leader over Huawei in all categories, which is also confirmed by market performance.

Conclusions

This research study, based on a literature review and quantitative research, demonstrates that a structured brand management process is a key factor in building brand equity, positioning, and brand image. These elements create a competitive advantage, improve customer satisfaction, and influence consumer choice.

The research results, obtained from Apple and Huawei users, confirm that strategic brand management strongly impacts product quality, customer choice, and overall satisfaction. Brand equity also contributes to financial performance, as strong brands can command a price premium while maintaining high customer satisfaction.

The research findings show that Apple users have significantly higher satisfaction across all measured aspects compared to Huawei users, including built-in quality, timely software updates, video and photo quality, price satisfaction, and tendency to upgrade to new models. Apple is thus the clear leader in customer satisfaction and perceived product quality.

Based on the findings, Huawei can improve its market position by expanding into new markets with differentiated products, improving internal operations and efficiency, rebranding toward higher-end offerings, and strengthening its management and talent development to create sustainable competitive advantages.

Apple's competitive advantage remains its exceptional customer experience, strong ecosystem, and emotional brand appeal. Its retail strategy and user-friendly interface reinforce brand loyalty and create a strong sense of community among users.

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A APPENDICES

In the appendix section, three levels of Appendix headings are available.

A.1 General Guidelines

1. Save as you go and backup your file regularly.
2. Do not work on files that are saved in a cloud directory. To avoid problems such as MS Word crashing, please only work on files that are saved locally on your machine.
3. Equations should be created with the built-in Microsoft® Equation Editor included with your version of Word. (Please check the compatibility at http://tinyurl.com/lzny753 for using MathType.)
4. Please save all files in DOCX format, as the DOC format is only supported for the Mac 2011 version.
5. Tables should be created with Word's "Insert Table" tool and placed within your document. (Tables created with spaces or tabs will have problems being properly typeset. To ensure your table is published correctly, Word's table tool must be used.)
6. Do not copy-and-paste elements into the submission document from Excel such as charts and tables.
7. Footnotes should be inserted using Word's "Insert Footnote" feature.
8. Do not use Word's "Insert Shape" function to create diagrams, etc.
9. Do not have references appear in a table/cells format as it will produce an error during the layout generation process.
10. MS Word does not consistently allow the original formatting to be modified in the text. In these cases, it is best to copy all the document's text from the specific file and paste into a new MS Word document and then save it.
11. At times there are font problems such as "odd" stuff/junk characters that appear in the text, usually in the references. This can be caused by a variety of reasons such as copying-and-pasting from another file, file transfers, etc. Please review your text prior to submission to make sure it reads correctly.

A.1.1 Preparing Graphics

- Accepted image file formats: TIFF (.tif), JPEG (.jpg).
- Application files (e.g., Corel Draw, MS Word, MS Excel, PPT, etc.) are NOT recommended.
- Images created in Microsoft Word using text-box, shapes, clip-art are NOT recommended.
- Scalable vector formats (i.e., SVG, EPS and PS) are greatly preferred.
- IMPORTANT: All fonts must be embedded in your figure files.
- Set the correct orientation for each graphics file.

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