



VOLUME 1, ISSUE 3  
OCTOBER 2025

# INTERNATIONAL JOURNAL OF DIGITAL RESEARCH



E-ISSN 3033-179X



[IJDR.NET](http://IJDR.NET)

**INTERNATIONAL JOURNAL  
OF  
DIGITAL RESEARCH**

**VOLUME 1**

**ISSUE 3**

**OCTOBER**

**2025**

**International Journal of Digital Research**  
is abstracted and indexed in:





Dimensions

© 2025 International Journal of Digital Research

Publisher: Digital Research Lab Blagoevgrad | Registered by Bulgarian and EU  
legislation with Unified Identity Code (BULSTAT) 181324025

Address: 35 Aleksandar Stamboliyski bul., Blagoevgrad, Bulgaria, EU – 2700

## EDITORIAL BOARD

**Dr. Vladimir Karadzhov – Editor in Chief** - Faculty of Mathematics and Natural Sciences, South-West University “Neofit Rilski” – Blagoevgrad, Bulgaria

**Prof. Dr. Mariya Kicheva-Kirova** - South-West University “Neofit Rilski” – Blagoevgrad, Bulgaria - Faculty of Economy; Vice President of the College of Tourism – Blagoevgrad

**Assoc. Prof. Dr. Stoyan Kirov** - Rector of the College of Tourism – Blagoevgrad

**Assoc. Prof. Dr. Plamen Patarchanov** - Head of the Department of Social and Economic Geography, Faculty of Geology and Geography, Sofia University “St. Kliment Ohridski” – Sofia, Bulgaria

**Assoc. Prof. Dr. Emilia Patarchanova** - Head of the Department of Geography, Ecology and Environmental Protection, Faculty of Mathematics and Natural Sciences, South-West University “Neofit Rilski” – Blagoevgrad, Bulgaria

**Prof. Dr. Ana Pego** - Researcher at the Centre for Research in Tourism, Sustainability and Well-being, Economic Faculty, University of Algarve - Faro, Portugal

## EDITORIAL TEAM

**Prof. Dr. Stefan Kirilov** – College of Tourism – Blagoevgrad, Bulgaria

**Prof. Dr. Carolina Cassiano** – University of São Paulo – São Paulo, Brazil

**Prof. Dr. Mariana Dominguez Villaverde** – Grenoble Alpes University – Grenoble, France

**Prof. Dr. Mónica Guadalupe Chávez Elorza** – Universidad Autónoma de Zacatecas “Francisco García Salinas” – Zacatecas, Mexico

**Prof. Dr. Ahmad A. Al Rababah** – King Abdulaziz University – Saudi Arabia

**Assoc. Prof. Dr. Bojan Đerčan** – University of Novi Sad – Novi Sad, Serbia

**Assoc. Prof. Dr. Enkeleida Lleshi** – Head of the Department of Sports Performance – Sports University of Tirana – Tirana, Albania

**Assoc. Prof. Dr. Raya Stoyanova** – Technical Faculty - South-West University “Neofit Rilski” – Blagoevgrad, Bulgaria

**Assoc. Prof. Dr. Velislava Simeonova** – University of Barcelona – Barcelona, Spain

**Chief Assist. Prof. Dr. Blaga Rousseva** –  
Doctor of Psychology – Military  
Medical Academy (VMA) – Sofia,  
Bulgaria

**Chief Assist. Prof. Dr. Kaloyan Tsvetkov**  
– Sofia University “St. Kliment  
Ohridski” – Sofia, Bulgaria

**Assist. Prof. Dr. Humera Amin** –  
University of Sargodha – Sargodha,  
Punjab, Pakistan

**Assist. Prof. Dr. Krasimir Spasov** –  
American University in Bulgaria  
(AUBG) – Blagoevgrad, Bulgaria

**Assist. Prof. Dr. Khalil Ahmad** – Balaji  
Institute of Modern Management –  
Pune, India

**Dr. Anita Andziak** – Swiss School of  
Business and Management Geneva,  
Genève, Switzerland

**Dr. Antony Hoyte-West** – Independent  
Researcher – Oxford, United Kingdom

**Dr. Artan Pogoni** – Faculty of Social  
Science, Tourism and Sport – Barleti  
University – Tirana, Albania

**Dr. Janet C. Kimeto** – University of  
Kabianga – Kericho, Kenya

**Dr. Todor Kondarev** – Independent  
Researcher – New Bulgarian  
University (NBU) – Sofia, Bulgaria

**Dr. Sebiha Madanska** – Paisii Hilendarski  
University of Plovdiv – Plovdiv,  
Bulgaria

**Dr. Stoyan Vezekov** – Research Director  
at Center for Applied Neuroscience  
Vezekov – Sofia, Bulgaria

---

## CONTENTS

<b>HOW TO CREATE THE BEST PESTEL ANALYSIS .....</b>	<b>8</b>
<i>Vladimir Karadzhov, Emilia Patarchanova</i>	
<b>FOREIGN DIRECT INVESTMENTS IN TRAKIA ECONOMIC ZONE: MODELS AND ECONOMIC EFFECTS .....</b>	<b>21</b>
<i>Olga Gavrilova</i>	
<b>INFLUENCE OF SOCIAL NETWORKS ON THE SUBJECTIVE FEELINGS OF LONELINESS IN ADOLESCENTS AND YOUTH .....</b>	<b>35</b>
<i>Teodor Gergov, Tsvetelina Hadzhieva</i>	
<b>THE IMPACT OF ICT ON ACTIVE TOURISM: A SYSTEMATIC LITERATURE REVIEW OF INNOVATION, SMART TOURISM, AND SUSTAINABLE DEVELOPMENT .....</b>	<b>46</b>
<i>Anduela Lile, Eglantina Kalluçi, Arben Kaçurri</i>	
<b>THE ROLE OF EUROPEAN UNION'S AGRICULTURAL POLICY IN THE DEVELOPMENT OF RURAL AREAS IN BULGARIA .....</b>	<b>53</b>
<i>Valentin Shlyakov</i>	
<b>HISTORICAL AND CONTEMPORARY ANALYSIS OF CLIMATE CHANGE AND PM<sub>10</sub> AIR POLLUTION IN PLOVDIV .....</b>	<b>72</b>
<i>Krasimir Stoyanov, Galina Bezinska, Ruslana Ivanova-Dobrev</i>	
<b>TANNINS: PLANT-DERIVED POLYPHENOLS THAT ENHANCE SKIN HEALING .....</b>	<b>82</b>
<i>Mateus Domingues de Barros, Rebeca Xavier da Cunha, João Ricardhis Saturnino de Oliveira, Ana Paula Sant'Anna da Silva, Layza Fernanda Gomes Bezerra, Vera Lúcia de Menezes Lima</i>	
<b>GEOGRAPHICAL STUDIES OF URBANIZATION PROCESSES AND THEIR SPATIAL ORGANIZATION IN BULGARIA .....</b>	<b>110</b>
<i>Evelina Filatova, Emilia Patarchanova</i>	

# How to Create the Best PESTEL Analysis

Vladimir Karadzhov<sup>1</sup>, Emilia Patarchanova<sup>2</sup>

<sup>1</sup> Chief Assistant Professor, PhD, <sup>2</sup> Associate Professor, PhD

<sup>1,2</sup> Department of Geography, Ecology and Environmental Protection, Faculty of Mathematics and Natural Sciences, South-West University “Neofit Rilski”, Blagoevgrad, Bulgaria

<sup>1</sup> ORCID ID: 0000-0002-7514-5517, <sup>2</sup> ORCID ID: 0000-0002-1806-557X

Corresponding Author: Vladimir Karadzhov [karadzhov@swu.bg](mailto:karadzhov@swu.bg)

<https://doi.org/10.63711/ijdr.net20250301>

## ABSTRACT

This article offers a comprehensive and practical framework for creating an effective PESTEL analysis – one of the most widely used tools for macro-environmental scanning in strategic planning. The study begins by examining the theoretical foundations and academic evolution of the PESTEL framework across multiple domains, including management, marketing, innovation, and public policy. A detailed four-step guide is then proposed to support practitioners and researchers in conducting insightful and action-oriented analyses, enriched by examples, figures, and best practices. Emphasis is placed on common errors, contextual adaptation, and the value of scenario thinking in applying the tool to real-world decisions. A key contribution of this paper is the introduction of a Quantified PESTEL approach, which moves beyond qualitative judgment by incorporating structured, multi-criteria decision-making techniques such as AHP (Analytic Hierarchy Process), DEMATEL (Decision-Making Trial and Evaluation Laboratory), and ANP (Analytic Network Process). This methodology enables the assignment of measurable weights to each environmental factor and reveals interdependencies between them, ultimately producing a more data-driven and rigorous assessment of external conditions. A visualized model and summary table are provided to demonstrate how these tools can enhance the depth and reliability of PESTEL outcomes. The article concludes with practical insights and a call for future research exploring dynamic, sector-specific, or AI-supported applications of the PESTEL methodology.

**Keywords:** *PESTEL Analysis, Strategic Planning, Quantified PESTEL, Multi-Criteria Decision-Making, AHP, DEMATEL, ANP, Environmental Scanning, Management Tools, Scenario Analysis*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

In an era defined by rapid technological change, shifting geopolitical landscapes, environmental uncertainty, and evolving social dynamics, researchers require tools that can systematically assess the macro-environmental factors influencing their fields of study. The PESTEL analysis examines Political, Economic, Social, Technological, Environmental, and Legal dimensions. It has emerged as a versatile and widely recognized framework for such strategic environmental scanning.

While PESTEL is frequently cited and applied in business planning, public policy, and academic research, there remains a noticeable lack of a unified, academic-standard guide that clearly defines how

this tool should be applied within scholarly work. As a result, its use often varies in structure, depth, and quality, potentially limiting its analytical value and comparability across studies.

This review article addresses this gap by offering a comprehensive guide to PESTEL analysis, specifically designed for researchers. The aim is:

- To provide a standardized and practical framework for conducting PESTEL analyses in academic research;
- To emphasize the relevance and convenience of PESTEL as a tool for researchers across disciplines;
- To establish best practices and methodological standards that enhance the precision, credibility, and usefulness of the analysis.

By setting higher expectations for the use of PESTEL in research, this article seeks to empower scholars, doctoral students, and practitioners with a structured, adaptable, and academically sound approach to environmental analysis. Through examples, methodological insights, and interdisciplinary applications, it aspires to become a reference point for future studies employing PESTEL in strategic and analytical contexts. In doing so, it promotes greater consistency in the framework's application across disciplines, while encouraging critical thinking about the dynamic nature of macro-environmental influences. This guidance aims to support both novice and experienced researchers in achieving higher analytical depth and methodological transparency in their work.

## LITERATURE REVIEW

Understanding the theoretical foundation and practical evolution of PESTEL analysis is essential for applying the framework effectively in academic research. As a tool for macro-environmental scanning, PESTEL has undergone significant development since its inception, adapting to the complexities of modern strategic planning.

The PESTEL technique is also widely used in project risk analysis to identify macro-level threats and opportunities (Rastogi & Trivedi, 2016). Yüksel (2012) argues that integrating PESTEL with other strategic tools such as SWOT enhances multi-dimensional insight and aligns macro factors with internal capabilities. According to Sammut-Bonnici and Galea (2015), PESTEL serves as a scanning tool that allows organizations to map external changes systematically and anticipate strategic threats.

This section provides a critical overview of the scholarly literature on the origins, adaptations, and core purposes of PESTEL analysis. By tracing its transformation from a basic strategic model to a comprehensive analytical instrument, the review highlights its relevance across disciplines and its value as a methodological asset in evidence-based research.

### Evolution of PESTEL Analysis

The PESTEL analysis has evolved over decades as a fundamental tool for strategic environmental scanning. Its conceptual origin can be traced to Francis J. Aguilar, who introduced the "ETPS" framework – Economic, Technical, Political, and Social factors – in his 1967 book "Scanning the Business Environment" (Aguilar, 1967). This early model emphasized the importance of monitoring external influences for informed business decision-making.

During the 1980s, the framework expanded into PEST, incorporating Political, Economic, Social, and Technological dimensions. As awareness of legal and ecological factors grew, additional components were added: Legal and Environmental, forming the current PESTEL model (Sammut-Bonnici & Galea, 2015). The expanded version offers a more holistic view of external macro-environmental variables affecting organizational and societal development.

Recent literature highlights that PESTEL analysis is not static – it continues to evolve to meet the changing nature of global challenges. For instance, Bou Hatoum et al. (2023) illustrate how capital project organizations increasingly rely on PESTEL to adapt to geopolitical and environmental



uncertainties. In a similar vein, Belsare (2025) emphasizes that the model's adaptability makes it relevant for emerging economies, digital transformation research, and public policy planning.

### **Purpose and Application of PESTEL Analysis**

PESTEL analysis is primarily designed to identify and evaluate external factors that shape the environment in which an organization or policy operates. It enables a structured assessment of risks, opportunities, and trends by systematically analysing six critical dimensions: Political, Economic, Social, Technological, Environmental, and Legal (Corporate Finance Institute, n.d.). Its strength lies in the capacity to break down complex environments into manageable, researchable components.

Academic applications of PESTEL are widespread. Sridhar, Perera, and Bangera (2016), for example, applied the model to coastal zone management, revealing how political and environmental factors influence sustainability outcomes. Meanwhile, in business contexts, the tool is frequently employed to support long-term strategic planning, especially in volatile or transitional environments (Bou Hatoum et al., 2023).

As a result, PESTEL is not only useful for market evaluation or corporate planning, but also for conducting sectoral assessments, formulating public policies, and guiding academic inquiry. However, despite its broad usage, there is still a lack of standardized methodological guidance on how to effectively conduct a PESTEL analysis in academic settings – a gap this article seeks to address.

### **Methodological Innovations and Emerging Trends in PESTEL**

Recent academic contributions critically examine and refine the traditional use of PESTEL analysis, advocating for dynamic, adaptive, and technology-enhanced frameworks. Andersen (2025), for instance, systematically reviews over 20 variants of the PESTEL model (including STEEPLE and DESTEP), emphasizing that scholars should not treat the framework as a rigid checklist, but rather adapt it to the contextual dynamics of the research problem.

In applied research, particularly in engineering and construction studies, the PESTEL model has been used to categorize and compare external barriers to innovation. Olayiwola et al. (2025) conducted a systematic review of 56 studies on off-site construction and identified the PESTEL categories as crucial in evaluating institutional, economic, and social readiness.

Similarly, Kansongue et al. (2023) integrated PESTEL and SWOT in a study on renewable energy deployment in West Africa, demonstrating the importance of overlapping methodological tools to capture both environmental factors and internal capacities.

Andersen (2025) also warns that traditional PESTEL applications risk oversimplifying macro-environmental complexity by treating external factors as isolated categories. He critiques the lack of feedback mechanisms and interdependencies between dimensions such as Political and Legal or Technological and Environmental, advocating instead for adaptive and iterative models that reflect real-world interactions and uncertainty.

In the context of digital transformation and sustainability assessments, scholars have also begun exploring AI-supported decision models that align well with PESTEL dimensions. Farahdel et al. (2024) present a review of multi-criteria decision-making tools and propose integrating environmental scanning frameworks like PESTEL into digital sustainability evaluation.

These innovations signal a shift from static external scans toward a more dynamic, predictive, and interdisciplinary use of PESTEL, particularly in areas such as environmental governance, technology foresight, and risk management.

## **MATERIALS & METHODS**

This article is based on a narrative literature review combined with a methodological synthesis designed to identify, analyze, and consolidate best practices related to the application of the PESTEL analysis in academic and applied research settings. The approach aims to bridge the gap between



theoretical knowledge and practical implementation by offering researchers a structured guide for conducting high-quality environmental scanning using the PESTEL framework.

### Literature Selection Criteria

The literature review focused on peer-reviewed journal articles, academic monographs, and reputable institutional sources published between 2000 and 2025. Searches were conducted across major academic databases including Scopus, Web of Science, Science Direct, and Google Scholar. The primary search terms included: *PEST analysis*, *PESTEL analysis*, *macro-environmental scanning*, *strategic analysis tools*, and *environmental frameworks*. Preference was given to sources with active DOI registration to ensure academic reliability, traceability, and replicability.

### Data Extraction and Thematic Synthesis

Following initial screening and relevance assessment, the most pertinent sources were coded and thematically organized according to their focus on:

- (1) historical and theoretical development,
- (2) cross-disciplinary academic usage,
- (3) applied and comparative case studies,
- (4) methodological guidance, and
- (5) critiques and innovations in PESTEL implementation.

The synthesis process used comparative content analysis to identify recurring themes, theoretical gaps, and emerging trends in the use of PESTEL analysis across academic fields. From this, a conceptual framework and set of best practices were derived, serving as the foundation for the guidance presented in the Results and Discussion section..

## COMPONENTS OF PESTEL

The PESTEL framework consists of six key macro-environmental dimensions: Political, Economic, Social, Technological, Environmental, and Legal. Each component captures a specific external domain that can influence organizational strategy, policymaking, or research findings (Fig. 1). For researchers, clearly defining and contextualizing each dimension is essential for methodological rigor and analytical depth. Below is an overview of each component, including its scope and typical areas of application.

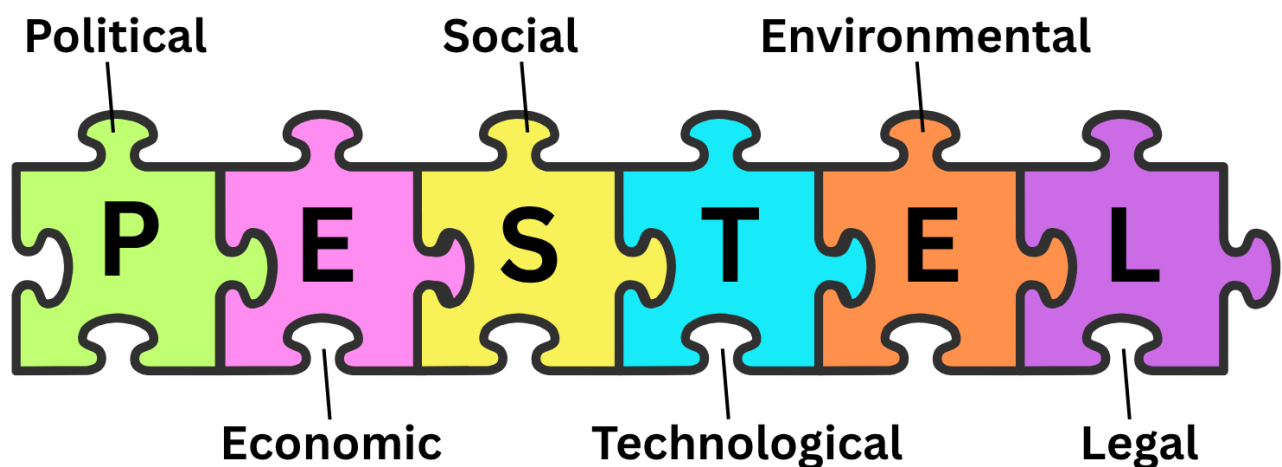


Figure 1. PESTEL Analysis Framework. *Source: The Authors*

### **Political Factors (P)**

Political factors refer to how government actions, political stability, and public policies affect a given environment. These include government regulations, tax policies, trade restrictions, political ideologies, and international relations. For researchers, political analysis may involve studying the influence of government interventions on markets, regulatory risk, or policy changes impacting a specific sector. In countries with unstable political systems, for instance, investment risks may be higher, shaping research in economics, tourism, or development studies.

Example: The introduction of protectionist trade policies in the United States under the Trump administration significantly influenced global supply chains and foreign investment flows, prompting studies in international business and economics.

### **Economic Factors (E)**

Economic factors assess the macroeconomic conditions that shape the economic landscape, such as GDP growth rates, inflation, interest rates, exchange rates, and employment trends. These variables are critical in determining market viability, investment decisions, and financial sustainability. Economic analysis in PESTEL often uses data from national statistics offices, the IMF, or the World Bank to identify trends and challenges.

A foundational understanding of the business environment can be developed using PESTEL analysis, which Gupta (2013) describes as a tool for decoding the external landscape in strategy formulation. Kew and Stredwick (2017) emphasize that understanding external forces via frameworks like PESTEL is a critical component of managing the modern business environment.

Example: Researchers studying consumer behavior may correlate inflationary pressure with changes in spending patterns, particularly in sectors like retail or hospitality.

### **Social Factors (S)**

Social or sociocultural factors encompass demographic trends, cultural values, education levels, social mobility, lifestyle preferences, and health indicators. These variables help explain how societal changes affect consumer needs, labor markets, or public services. For research purposes, understanding social context is crucial when analyzing human behavior, public health systems, or educational outcomes.

Example: Aging populations in countries like Japan and Germany have driven demand for healthcare innovation and automation, influencing both social policy and market research.

### **Technological Factors (T)**

Technological factors include innovation trends, R&D activity, technology adoption rates, digital infrastructure, and emerging technologies such as AI, IoT, or blockchain. This domain is particularly relevant in fast-evolving sectors like information technology, fintech, or education. Technological foresight and diffusion studies are often integrated within PESTEL to explore the transformative potential of innovation.

In the context of digital entrepreneurship, Fernandez-Portillo, Almodóvar-González, and Díaz-Casero (2022) applied the PESTEL model to examine technological and policy-related disruptions.

Example: The rapid adoption of digital platforms during the COVID-19 pandemic accelerated the growth of remote work and e-learning, prompting studies on productivity, digital literacy, and access equity.

### **Environmental Factors (E)**

Environmental factors refer to ecological and sustainability-related issues, including climate change, resource scarcity, environmental regulations, carbon emissions, and corporate environmental responsibility. These considerations are increasingly central to research in fields such as environmental science, sustainable development, and corporate social responsibility.



To enhance the rigor of environmental scanning, scholars have proposed incorporating multi-criteria decision-making (MCDM) techniques into frameworks like PESTEL, especially when prioritizing external factors (Ho, Xu, & Dey, 2010). Case studies such as Kajanus et al. (2012) demonstrate how PESTEL can be applied in environmental and natural resource planning through decision-support models. Environmental scanning techniques such as PESTEL can also act as drivers of innovation, especially when aligned with sustainability goals (Valls & Bagur-Femenías, 2017).

Example: The European Union’s Green Deal policy has spurred research on decarbonization strategies and environmental impact assessments within heavy industries and transportation.

### **Legal Factors (L)**

Legal factors address the formal regulatory frameworks and legal obligations that organizations and individuals must comply with. These include labor laws, consumer protection regulations, intellectual property rights, antitrust laws, and health and safety standards. Legal analysis helps researchers evaluate institutional constraints, compliance burdens, and the legal environment’s role in shaping business or policy outcomes.

Example: Studies on the gig economy often explore how changing labor laws impact platforms like Uber or Deliveroo, especially in relation to worker classification and rights.

## **RESULTS AND DISCUSSION – PESTEL BEST PRACTICES**

This section presents a synthesis of best practices for applying PESTEL analysis in academic research, derived from the literature review and methodological synthesis. The recommendations aim to enhance analytical rigor, comparability across studies, and interdisciplinary relevance. Figure 2 illustrates a simplified four-step model for conducting a PESTEL analysis, which serves as a foundation for the deeper practices discussed below.

### **1. Define the Objective and Scope of the Analysis**

The starting point for any PESTEL analysis should be a clearly defined research objective and scope. Researchers must specify whether the analysis serves an exploratory, explanatory, or policy-supporting function. Narrowing the geographical, sectoral, or temporal scope avoids vague generalizations and improves the precision of environmental scanning.

Best Practice: Link the PESTEL framework directly to the central research question or hypothesis.

Example: A study examining the impact of technological disruption on public education systems should clearly focus the analysis on the education sector, over a defined policy period (e.g., 2020–2030), and within a specific national context.

### **2. Use Reliable and Interdisciplinary Data Sources**

Each dimension of PESTEL requires data from distinct and often disciplinary-specific sources. Political and legal factors may be derived from government reports or international treaties, while social or technological factors require indicators from statistical agencies, academic publications, or industry-specific databases. Best Practice: Combine quantitative indicators with qualitative insights for a balanced and multi-dimensional evaluation. Example: When analyzing environmental factors in the energy sector, include both emissions data (quantitative) and policy trends from EU Green Deal legislation (qualitative).

### **3. Contextualize Factors with Critical Commentary**

Rather than listing factors mechanically, researchers should interpret them in light of existing theories, trends, and contextual dynamics. This helps avoid superficial or checklist-style reporting and promotes analytical depth.

Best Practice: Integrate scholarly literature to support factor interpretation and link them to broader systemic or sectoral trends.



Example: Instead of stating "rising inflation is an economic risk," connect it to consumer behavior shifts and investment volatility, citing relevant studies on macroeconomic impacts.

#### 4. Highlight Interdependencies Between Dimensions

One major limitation of traditional PESTEL applications is the artificial separation of factors. However, legal and political issues often overlap, and social values influence environmental regulation. Acknowledging these interdependencies leads to a more realistic understanding of the external environment.

Best Practice: Identify and briefly explain at least two cross-dimensional interactions within the analysis.

Example: Political decisions on renewable energy subsidies directly affect technological investment and social acceptance, creating a feedback loop between the P, T, and S dimensions.

#### 5. Adapt the Framework to Fit the Research Context

While PESTEL provides a standard structure, researchers should remain flexible and adapt it where appropriate. In some cases, additional categories (e.g., Ethical or Demographic) may be justified. Alternatively, hybrid models such as PESTEL-SWOT can enhance strategic insights.

Best Practice: Justify any modifications or extensions to the standard PESTEL model, citing relevant methodological literature.

Example: In sustainability research, integrating a "Sustainability" (SUS) dimension into PESTEL may be useful, as proposed by Farahdel et al. (2024), allowing a deeper focus on ESG-linked criteria.

#### 6. Synthesize Findings for Strategic or Policy Implications

The ultimate goal of PESTEL in research is to inform decision-making, theory-building, or scenario planning. Summarizing the main risks, opportunities, and trends helps translate analytical findings into actionable knowledge.

Table 1. Summary of the best PESTEL practices. *Source: The Authors*

	Best Practice Step	Key Recommendation	Example
1	Define Objective and Scope	Link PESTEL directly to research question or hypothesis	Education sector, 2020–2030, national policy focus
2	Use Reliable and Interdisciplinary Data Sources	Use a mix of qualitative and quantitative data from multiple disciplines	Combine EU legislation with emissions data
3	Contextualize Factors with Critical Commentary	Interpret findings using literature and contextual analysis	Connect inflation to consumer behavior using studies
4	Highlight Interdependencies Between Dimensions	Explain at least two cross-dimensional interactions	Show how political decisions impact tech and society
5	Adapt Framework to Research Context	Modify framework only with justification and references	Add "Sustainability" dimension for ESG research
6	Synthesize Findings for Strategic Implications	Use tables/matrices to summarize risks, trends, and opportunities	Rank factors by urgency or change likelihood



Best Practice: Use tables or matrices to visually communicate key insights and emphasize relevance to stakeholders or future studies.

For example, a final table could rank the most impactful macro-environmental factors by urgency or likelihood of change over the study horizon.

In alignment with established practice-oriented guidance, the PESTEL analysis process can be distilled into four essential steps: understanding the external environment, identifying key influencing factors, evaluating their potential impact, and acting upon the insights (Fig. 2). This structured flow, as summarized by Jalan (2024), provides a clear roadmap that enhances methodological consistency while retaining flexibility across different academic disciplines.

When visualized, as in Figure 2, the model serves as both a checklist and a cognitive map that guides researchers through the complexity of environmental scanning in a logical and accessible manner.

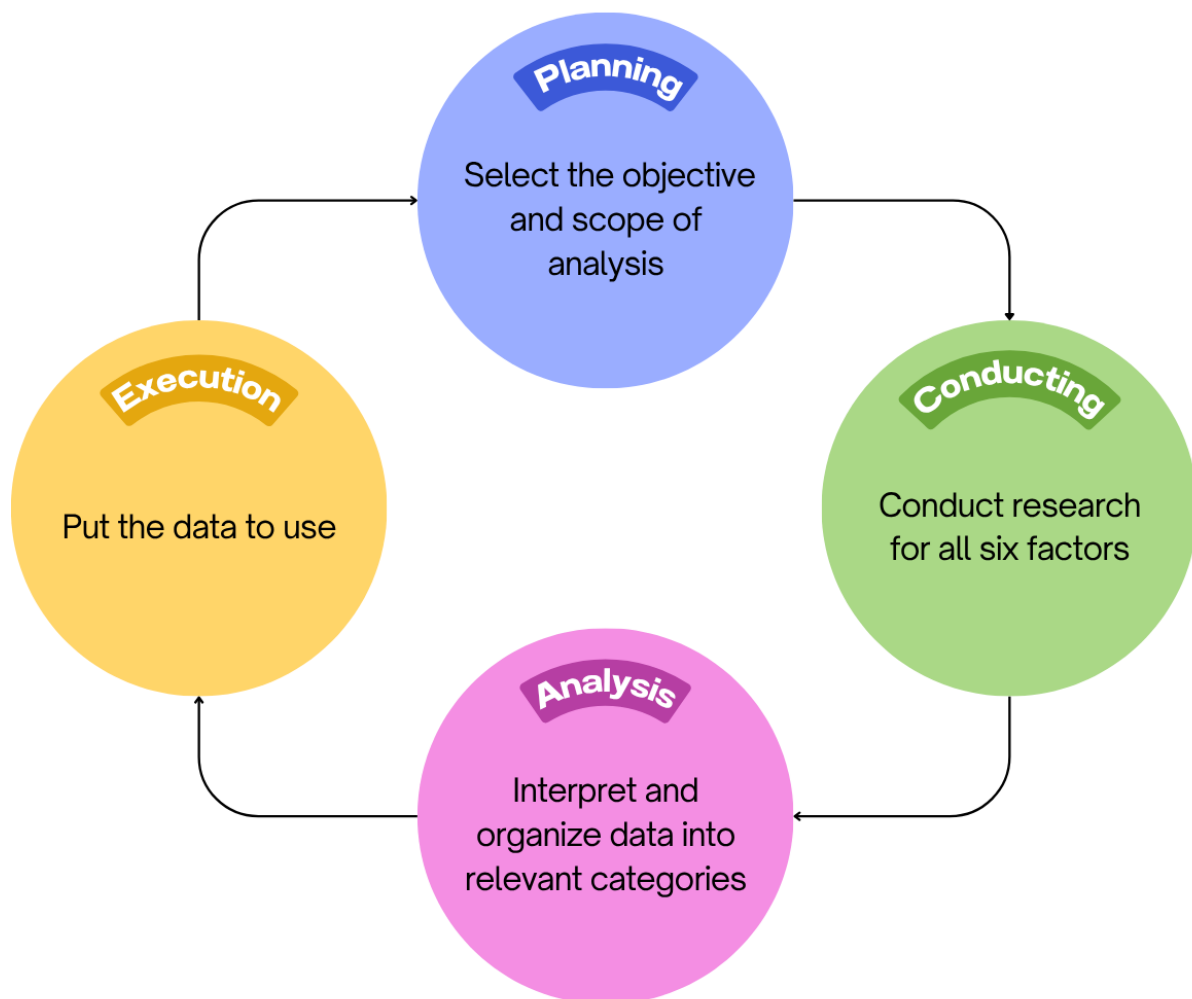


Figure 2. How to Conduct a PESTEL Analysis - Four Basic Steps.

Source: The Authors, based on Jalan, A. (2024).

While this four-step model is widely adopted in business and management contexts, its academic application requires greater depth and critical reflection. Researchers are encouraged to go beyond surface-level identification and interpretation, incorporating interdisciplinary literature, quantifiable indicators, and context-specific commentary into each stage.

Thus, while the figure provides a simplified conceptual entry point, the academic utility of PESTEL lies in how rigorously and reflexively each step is operationalized within the broader research design (Jalan, 2024).

## QUANTIFIED PESTEL APPROACHES

As the PESTEL framework gains traction across academic and applied fields, scholars have increasingly emphasized the need to transition from purely qualitative assessments toward more structured, quantitative interpretations. This emerging shift – often referred to as “quantified PESTEL” – allows for the objective weighting and prioritization of macro-environmental factors, making the model more actionable for strategic decision-making. Rather than treating each category equally, researchers use decision-support tools to analyze relationships between factors, rank their importance, and calculate overall environmental favorability.

One of the most influential contributions in this regard is the study by Yüksel (2012), who developed a multi-criteria decision-making model that integrates DEMATEL (Decision-Making Trial and Evaluation Laboratory), AHP (Analytic Hierarchy Process), and ANP (Analytic Network Process) into a unified PESTEL structure. In this model, researchers begin by identifying specific sub-factors for each of the six PESTEL dimensions. DEMATEL is then applied to analyze the causal relationships and interdependencies between these dimensions, highlighting which factors exert the most influence. AHP is used to calculate local weights for each sub-factor based on expert evaluation, while ANP aggregates these scores into global weights that reflect both importance and influence. The resulting model transforms the conventional PESTEL into a dynamic, weighted diagnostic tool that can classify external environments as supportive, neutral, or unsupportive for specific decisions or organizations.

Table 2. Quantified PESTEL Weights Using AHP, DEMATEL, and ANP (Based on Chutipongdech, 2022; Yüksel, 2012)

PESTEL Dimension	Local Weight (AHP)	Interdependency Influence (DEMATEL)	Global Weight (ANP)
Political	0.15	Moderate	0.14
Economic	0.18	High	0.20
Social	0.12	Low	0.10
Technological	0.22	High	0.21
Environmental	0.05	Low	0.06
Legal	0.28	Very High	0.29

Table 2 illustrates the output of a quantified PESTEL analysis using a hybrid decision-making methodology that combines AHP, DEMATEL, and ANP. The Legal dimension emerges as the most influential factor, receiving the highest global weight (0.29), closely followed by Technological (0.21) and Economic (0.20) aspects. This suggests that regulatory frameworks and digital innovation are perceived as critical drivers in the external macro-environment. Meanwhile, Environmental and Social dimensions exhibit comparatively lower global weights, reflecting their lesser strategic impact in the analyzed context. The integration of interdependency analysis (via DEMATEL) highlights how certain dimensions – particularly Legal and Technological – exert cascading influence over others, thereby justifying their weighted prioritization in the final model. These findings reinforce the utility of



quantitative PESTEL in enhancing decision-making by transforming subjective assessments into structured, evidence-based insights.

Additional case studies reinforce the utility of this approach. For instance, Chutiphongdech (2022) applied a PESTEL-AHP framework to evaluate strategic challenges in Thailand's public airport sector. Based on expert input, the most critical macro-environmental factors were found to be legal and technological, which received weighted scores of 28% and 22%, respectively – highlighting how quantification can expose sector-specific risks. Similarly, Vardopoulos et al. (2021) introduced an integrated SWOT-PESTEL-AHP model for use in adaptive reuse planning for historic buildings. Their findings confirmed that quantitative environmental scanning can enrich sustainability-oriented planning and enable more transparent prioritization of external pressures. Together, these models underscore a growing academic consensus: that the PESTEL framework, when empowered by multi-criteria analysis, can evolve into a more predictive and evidence-based tool for strategic evaluation.

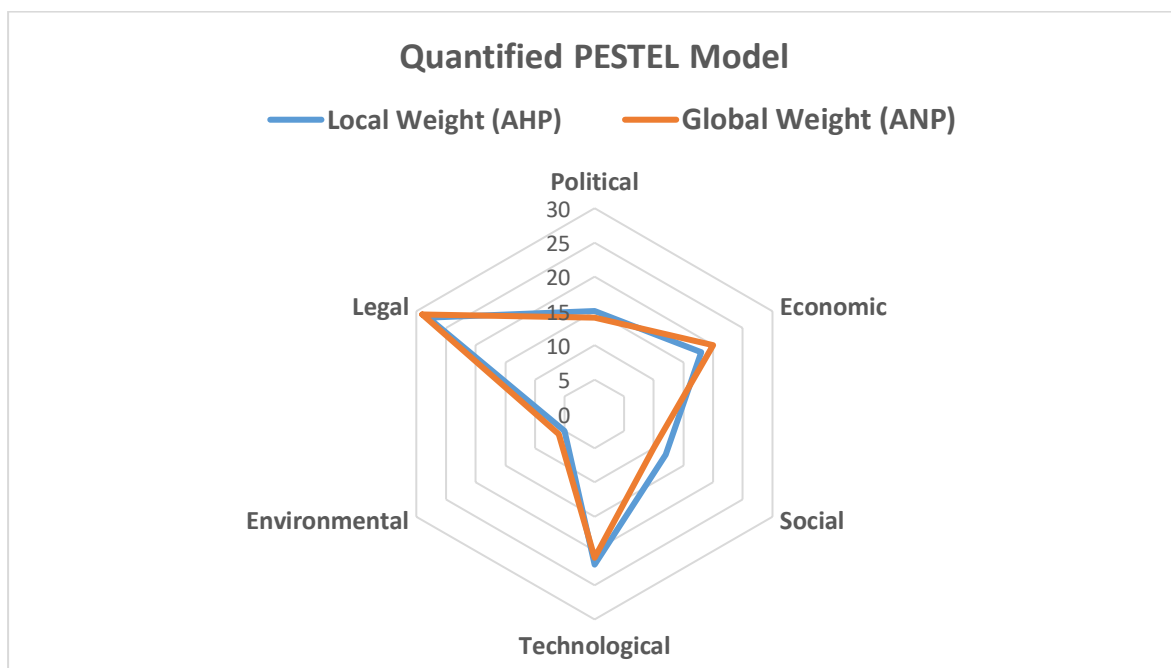


Figure 3. Quantified PESTEL Model: Weighted Influence of Each Dimension Using AHP, DEMATEL, and ANP. *Source: The Authors (Based on Chutiphongdech, 2022; Yüksel, 2012)*

Figure 3 presents the quantified impact of each PESTEL category based on a multi-criteria model incorporating AHP, DEMATEL, and ANP. The size and color of each segment reflect its global weight, while directional arrows may be used to illustrate interdependencies (inspired by DEMATEL results). Legal and Technological dimensions dominate the strategic landscape, underscoring their outsized influence in shaping external conditions for planning and evaluation.

Figure 4 visualizes the global weights of PESTEL categories as calculated via a hybrid model combining AHP, DEMATEL, and ANP. Legal (29%) and Technological (21%) dimensions hold the greatest strategic influence, while Social (10%) and Environmental (6%) factors rank lower in the analyzed context. Interdependencies (arrows) indicate cross-influences between categories, derived from expert-based causal mapping.

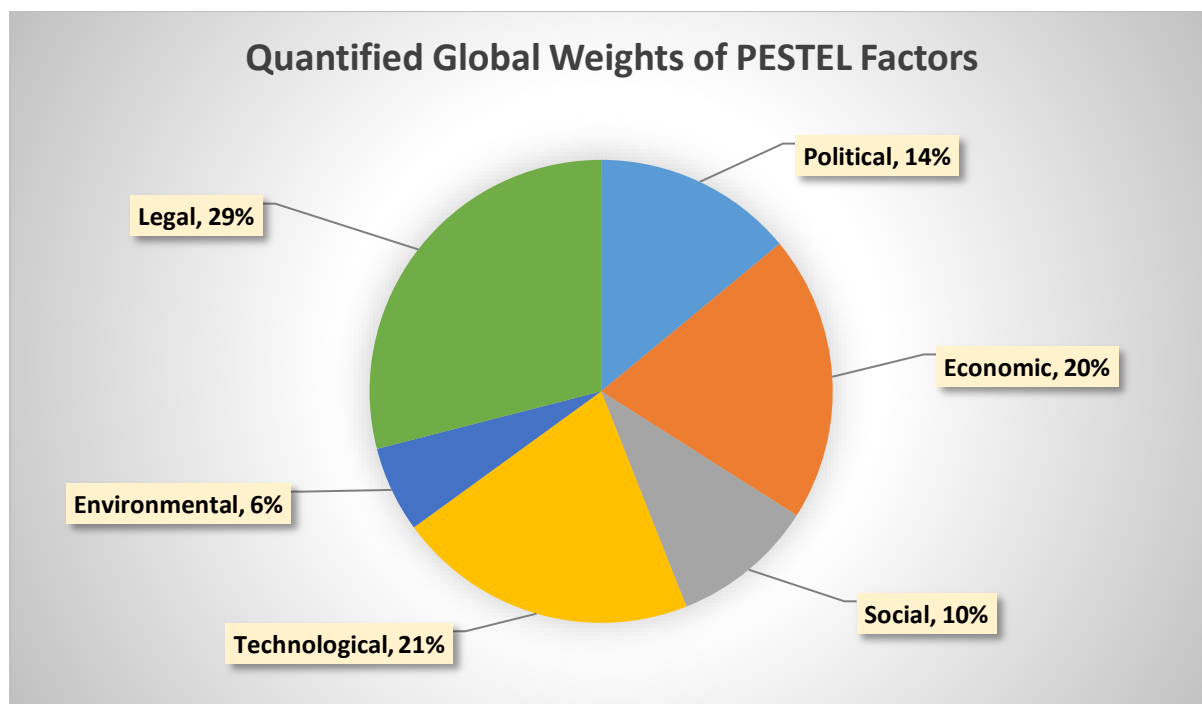


Figure 4. Quantified PESTEL Model: Relative Importance of External Factors.

*Source: The Authors (Based on Chutiphongdech, 2022; Yüksel, 2012)*

The integration of quantitative methodologies into the PESTEL framework represents a meaningful evolution in strategic analysis, bridging the gap between qualitative insight and data-driven decision-making. By applying tools such as AHP, DEMATEL, and ANP, organizations and researchers gain the ability not only to identify external pressures but also to measure and prioritize them with empirical precision. As such models become more accessible and adaptable across sectors, Quantified PESTEL is poised to become an essential extension of traditional environmental scanning. This shift paves the way for more informed strategic planning – one that is grounded in both expert judgment and measurable influence. The following conclusion summarizes the key contributions of this paper and outlines best practices for the future use of the PESTEL methodology.

## CONCLUSION

This article has provided a comprehensive and practice-oriented guide to creating a robust PESTEL analysis. From foundational concepts and literature trends to practical implementation steps and visual models, the paper serves as both an academic overview and a practical handbook. By outlining a four-step method and highlighting common challenges, the article helps both researchers and professionals enhance the strategic value of their macro-environmental analyses.

A significant contribution is the integration of Quantified PESTEL, offering a hybrid model that uses AHP, DEMATEL, and ANP to assign weights and reveal causal relationships among PESTEL dimensions. This advancement adds analytical depth and objectivity to an otherwise qualitative framework, making it more adaptable to data-driven and complex environments.

The findings suggest that PESTEL analysis, when designed carefully and supported by methodological rigor, remains a vital tool for strategic planning, especially in contexts shaped by uncertainty, regulation, and technological change. The article encourages future research to explore

dynamic applications of PESTEL – such as real-time analysis, AI-enhanced forecasting, or sector-specific adaptations – as well as its integration into more comprehensive decision-making ecosystems like TOWS, SWOT, or scenario modelling.

By bridging conceptual clarity with applied insights, the article aims to support both academic understanding and practical application of PESTEL as a decision-support tool for navigating today's volatile external environment.

### ***Declaration by Authors***

**Ethical Approval:** Approved

**Acknowledgement:** None

**Source of Funding:** None

**Conflict of Interest:** The authors declare no conflict of interest.

### **REFERENCES**

- Aguilar, F. J. (1967). *Scanning the business environment*. Macmillan.
- Andersen, M. S. (2025). From PEST to STEEPLE: Variants of External Environment Analysis Frameworks in Strategic and Energy Policy. *SSRN*. <https://doi.org/10.2139/ssrn.5266562>
- Belsare, H. V. (2025). PESTLE analysis. *International Journal of Advanced Research*, 13(2), 608–612. <https://doi.org/10.21474/IJAR01/20411>
- Bou Hatoum, M., Nassereddine, H., Musick, S., & El-Jazzar, M. (2023). Investigation of PESTEL factors driving change in capital project organizations. *Frontiers in Built Environment*, 9, 1207564. <https://doi.org/10.3389/fbuil.2023.1207564>
- Chutiphongdech, T. (2022). Industry analysis by PESTEL-AHP: A case study of Thailand public airports. *SSRN*. <https://doi.org/10.2139/ssrn.4084702>
- Corporate Finance Institute. (n.d.). *PESTEL analysis*. Retrieved March 31, 2025 <https://corporatefinanceinstitute.com/resources/management/pestel-analysis/>
- Farahdel, S., Abolhasani, M., Eghbali, A., & Soheili, N. (2024). Multi-Criteria Decision-Making Models in Organizational Sustainability Assessment: A Systematic Review. *arXiv*. <https://arxiv.org/abs/2403.04717>
- Fernandez-Portillo, A., Almodóvar-González, M., & Díaz-Casero, J. C. (2022). Digital entrepreneurship and external factors: A PESTEL approach. *Sustainability*, 14(5), 3055. <https://doi.org/10.3390/su14053055>
- Gupta, A. (2013). *Environmental and PEST analysis: An approach to external business environment*. *SSRN*. <https://doi.org/10.2139/ssrn.2299791>
- Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, 202(1), 16–24. <https://doi.org/10.1016/j.ejor.2010.04.041>
- Yüksel, İ. (2012). Developing a multi-criteria decision making model for PESTEL analysis. *Procedia - Social and Behavioral Sciences*, 1(58), 1525–1534. <https://doi.org/10.1016/j.sbspro.2012.09.057>
- Jalan, A. (2024). How to Conduct a PESTLE Analysis Explained with Example. *Upmetrics*. <https://upmetrics.co/blog/pestle-analysis>
- Kajanus, M., Leskinen, P., Kurttila, M., & Kangas, J. (2012). Making PESTEL decision models work in real-world scenarios. *Forest Ecology and Management*, 284, 63–71. <https://doi.org/10.1016/j.foreco.2012.03.027>



- Kansongue, A., Guemkam, G., & Afane, E. (2023). SWOT and PESTEL analysis of renewable energy deployment in Togo: Challenges and perspectives. *Frontiers in Sustainability*, 2, 990173. <https://doi.org/10.3389/frsus.2022.990173>
- Kew, J., & Stredwick, J. (2017). *Business environment: Managing in a strategic context* (4th ed.). Routledge. <https://doi.org/10.4324/9781315183675>
- Olayiwola, M., Chan, D. W. M., & Jin, R. (2025). Barriers to off-site construction implementation: A systematic review using PESTEL framework. *Buildings*, 15(13), 2146. <https://doi.org/10.3390/buildings15132146>
- Rastogi, V., & Trivedi, M. (2016). PESTLE technique – A tool to identify external risks in project management. SSRN. <https://doi.org/10.2139/ssrn.2748791>
- Sammut-Bonnici, T., & Galea, D. (2015). PEST analysis. *Wiley Online Library* (Vol. 12). <https://doi.org/10.1002/9781118785317.weom120113>
- Sridhar, R., Perera, C., & Bangera, S. (2016). A Political, Economic, Social, Technological, Legal and Environmental (PESTLE) approach for assessment of coastal zone management practice in India. *International Review of Public Administration*, 21(3), 216–232. <https://doi.org/10.1080/12294659.2016.1237095>
- Valls, J. F., & Bagur-Femenías, L. (2017). Environmental scanning as a driver of sustainable innovation. *Technological Forecasting and Social Change*, 119, 196–204. <https://doi.org/10.1016/j.techfore.2017.07.017>
- Vardopoulos, I., Della Spina, F., & Palma, P. (2021). An integrated SWOT–PESTLE–AHP model assessing sustainability and adaptive reuse of historical buildings. *Applied Sciences*, 11(15), 7134. <https://doi.org/10.3390/app11157134>

**How to cite this article:**

Karadzhev, V., E. Patarchanova (2025). How to Create the Best PESTEL Analysis. *International Journal of Digital Research*, E-ISSN: 3033-179X, Vol.1 (3): 8-20. <https://doi.org/10.63711/ijdr.net20250301>

\*\*\*\*\*



# Foreign Direct Investments in Trakia Economic Zone: Models and Economic Effects

**Olga Gavrilova**

PhD Student  
Department of Geography, Ecology and Environmental Protection  
Faculty of Mathematics and Natural Sciences,  
South-West University "Neofit Rilski", Blagoevgrad, Bulgaria  
ORCID ID: 0009-0007-9710-0073, E-mail: [olga.gavrilova@swu.bg](mailto:olga.gavrilova@swu.bg)

<https://doi.org/10.63711/ijdr.net20250302>

## ABSTRACT

Foreign direct investment (FDI) is a key element of international economic integration. It creates stable and sustainable relationships between economies, leads to increased labor productivity, improved product quality, and competitiveness. FDI promotes the creation of new jobs (increases employment and positively influences competition in the labor market), contributes to the transfer of knowledge, technology and know-how between countries, and stimulates consumption. As part of the global economy, FDI has a number of effects on the host country's economy - stimulating integration into global value chains, modernization of production, and increasing regional competitiveness. When implementing foreign investments, not only positive developments and favorable effects can be observed, but also negative ones. In the countries of Central and Eastern Europe, FDI is not only a source of financing for economic growth, but also a prerequisite for introducing new technologies, know-how and modern market management into production. It allows the host country to gain time in absorbing such technologies and shorten the duration of economic transformations. This study examines the processes of attracting FDI within the Trakia Economic Zone (TEZ) – one of the leading industrial zones in Bulgaria and Southeastern Europe. The TEZ is distinguished as the first and longest-standing industrial zone in Bulgaria, establishing itself as a leading model for successful development and investment attraction. Trakia Economic Zone is the first public-private partnership in Bulgaria, supported by the government and the Ministry of Economy. It is one of the largest industrial and logistics complexes in Bulgaria, encompassing several industrial zones located around the city of Plovdiv. The report analyzes investment patterns, the profile of foreign companies, as well as the economic effects of FDI on the socio-economic development of the region.

**Keywords:** *Foreign direct investment, Trakia economic zone, economic effects, investment models*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

In Bulgaria, numerous regulatory documents have been created to stimulate local investment activity; however, the anticipated positive outcomes have not materialized. Although there are various concepts and strategies aimed at attracting foreign investment, as well as a significant number of associations, confederations, local development agencies, and other formal and informal entities, these

efforts have not succeeded in generating the desired level of investment activity. This suggests that the establishment of governance bodies and civil society organizations does not always guarantee effectiveness, particularly when their interaction is poorly balanced. As North (2000) notes, *institutions represent the rules of the game, while organizations are the players*. Nonetheless, merely adhering to formal regulations is insufficient; it must be complemented by creativity and innovation (Milkova, 2016).

Foreign direct investment (FDI) represents a key component of local policies and regional marketing strategies, as it has the capacity to reshape and transform regional systems, influencing not only the economic but also the social and cultural dimensions of a given territory. Policymakers acknowledge the benefits of FDI for national economic development, including the creation of employment opportunities, the transfer of advanced technologies, the introduction of managerial expertise, the development of technical skills, and access to new foreign markets (Aitken & Harrison, 1999; Hill, 2000; Harding & Javorcik, 2011).

In the academic literature, foreign investments are generally classified into two main types—direct and indirect (portfolio) investments. Direct foreign investments involve capital flows abroad aimed at enabling the investor to exert direct influence over a company’s economic activities, with financial objectives and control potential being central considerations. In contrast, portfolio investments consist of acquiring foreign securities or other capital assets—such as shares, investment certificates, or fixed-income securities—without exercising direct influence over the targeted company. These are typically short-term in nature, undertaken primarily by private individuals, and driven by considerations of return and risk. Such investments are often speculative or focused on short-term yields from financial assets. Despite the growing importance of FDI in recent years, the scholarly literature still lacks a fully developed and systematized theory that explains why companies seek to expand their activities across national borders.

Existing theoretical frameworks address only certain dimensions of foreign direct investment (FDI), providing partial answers to questions such as why, how, where, in what manner, and in what form investors transfer their capital across national borders. This limitation stems from the dynamic nature of international economic integration processes, the diverse activities undertaken by transnational corporations (TNCs), and the wide variety of motives driving FDI. Some scholars adopt a macroeconomic perspective on the causes of capital flows, linking FDI to the balance of payments (J. M. Keynes, R. Harrod, E. Domar, 1959) and associating it with theories of foreign trade and comparative advantage (B. Olin, E. Heckscher, R. Vernon, V. Leontiev, 1979).

Other researchers focus on the behavior of investing firms themselves (St. Hymer, R. Caves, C. P. Kindleberger, 1970), developing microeconomic approaches. Macroeconomic theories of FDI, particularly within the neoclassical framework, regard capital as one of the factors of production, with its international movement determined by variations in returns or interest rates. Both classical and neoclassical perspectives emphasize the comparative advantages of nations, largely addressing the location decisions of TNCs. However, they often overlook a fundamental issue: why corporations choose to relocate production abroad rather than simply exporting finished goods, and how they succeed in competing with domestic firms in foreign markets.

Microeconomic theories, which gained traction in the second half of the twentieth century, argue that investment decisions abroad are not solely based on differences in marginal productivity or rates of return. Instead, they emphasize the role of unique tangible and intangible assets that confer competitive advantages on firms in international markets.

In Bulgaria, the legal framework for free economic zones was established in 1987 through Decree No. 2242, published in State Gazette No. 55 of 17 July 1987, accompanied by implementing regulations. The decree defined the procedures for creating free zones within the territory of the People's Republic of Bulgaria and set the conditions for conducting production, trade, and other economic activities within them. These zones were designed to stimulate entrepreneurial initiatives in manufacturing, service provision, trade, and other activities that diversify and expand exports. As a



policy tool for attracting investment, free economic zones offer substantial incentives, including customs and tax exemptions, for companies engaged in manufacturing, trading, or warehousing.

The present study seeks to examine the models for attracting and implementing FDI in the Trakia Economic Zone and to evaluate their influence on the region's economic development.

## MATERIALS & METHODS

This section presents the data sources and methods used in the study to objectively assess foreign direct investment and their impact on TEZ.

### Data Sources

**Analysis of statistical data** covers the dynamics of foreign direct investment in the TEZ through a quantitative assessment of their volume and their impact on key economic indicators such as value added and expenditure on acquisition of fixed assets. Statistical data are taken from the National Statistical Institute (NSI) and the TEZ.

**The qualitative analysis** in the study shows how FDI affects the local economy and infrastructure through the incentive and interest of investors, the efficiency of the resources used, and the socio-economic changes that occur in the region.

**Quantitative analysis**, through a regression method, allows for the establishment of statistical relationships between FDI and specific economic indicators - value added and costs of acquiring fixed assets.

The study also applied the **geospatial method**. It shows the location of the zone and the included industrial zones. The map included in the analysis shows the transport corridors that determine the logistical advantages and territorial dependencies in the zone.

## LITERATURE REVIEW

The establishment and expansion of industrial parks and zones in Bulgaria constitute a significant driver of economic growth and a means of attracting investment. A stable and well-developed industrial sector plays a crucial role in boosting economic performance, generating employment opportunities, and enhancing the country's export potential. The progress of industrial zones in Bulgaria is closely linked to the overall macroeconomic environment and business climate, the availability of incentives for foreign investors, and the prevailing conditions for investment implementation. Factors such as infrastructure quality, the level of education, and the availability of skilled labor are equally decisive. Furthermore, economic diversification, a favorable business environment, and the provision of high-quality services contribute positively to the attractiveness of these zones.

Bulgaria benefits from a strategic geographic position in Southeastern Europe, serving as a key transit point between Europe, the Middle East, and Asia. Notably, five of the ten Pan-European Transport Corridors (PTCs) – IV, VII, VIII, IX, and X – pass through its territory (Figure 1). This advantageous location not only facilitates connectivity but also strengthens the country's competitiveness in attracting investment.

Economic zones have increasingly proven to be an effective mechanism for concentrating investment activities. Among the leading organizational approaches to their management is the public-private partnership (PPP) model. This approach represents a sustainable framework for investment, enabling strategic collaboration between the state and the private sector. Through PPPs, resources can be used more efficiently, risks can be shared, and long-term economic benefits can be achieved.

A public-private partnership (PPP) is generally understood as a long-term cooperative arrangement between public institutions and private entities, in which both sides participate in the joint development of products or services and share the associated risks, costs, and resources. This

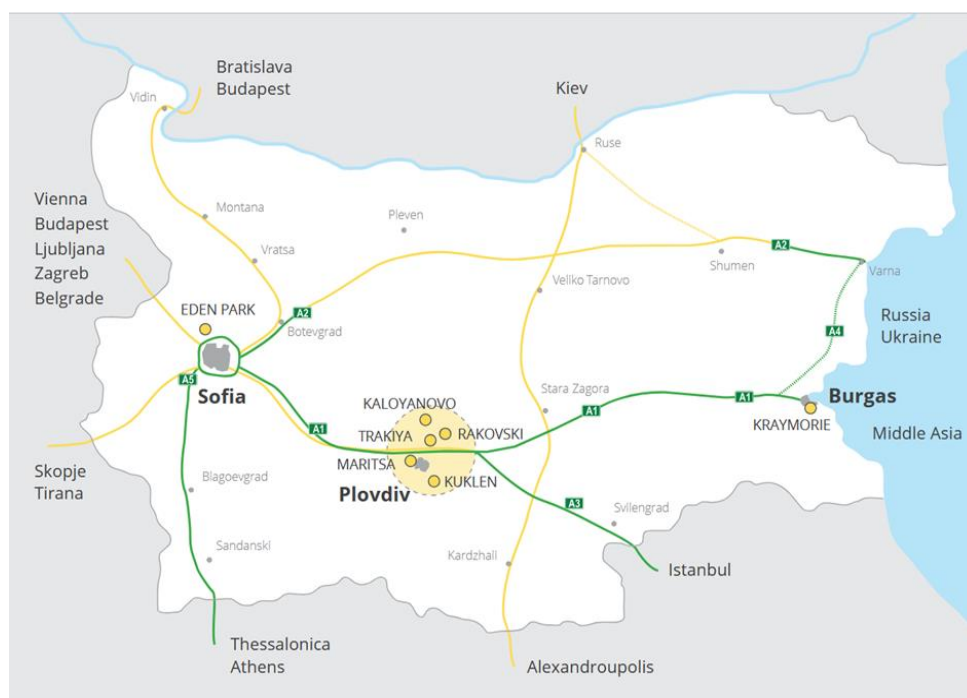


model is particularly relevant to the establishment of industrial parks and zones, as their creation exhibits many of the defining characteristics of such partnerships.

The overarching objective of PPPs in this context is to attract private investment into sectors that are considered priorities for the national economy. Industrial zones and parks inherently require sustained collaboration between public authorities and private investors. In a successful partnership, risks are distributed between the parties: public partners typically cover the expenses for planning and design, legal and administrative procedures, and the construction of supporting infrastructure, while private partners assume responsibilities related to site-specific investments, production activities, recruitment and training of qualified personnel, and the provision of stable employment.

The effectiveness of a PPP depends on several critical factors, including the presence of a favorable investment climate, the economic feasibility of the project, an appropriate distribution of risks, a sound financial structure, a capable and reliable concession consortium, and the achievement of predefined objectives. Both parties base their decision to engage in the partnership on a thorough cost–benefit analysis, resulting in a long-term contractual relationship that satisfies mutual interests.

Following the repeal of the Public–Private Partnership Act, the framework for PPPs in Bulgaria has been incorporated into the Concessions Act. According to Article 22, paragraph 2, a public–private company may be established for the purpose of concluding a concession agreement, structured as a capital-based commercial entity. In such a company, the concessionaire acts as the “private partner,” while the state, one or more municipalities, and/or a public enterprise designated by the grantor serve as the “public partner.” A notable example of this model in practice is the Trakia Economic Zone, developed through close cooperation between local authorities and major private investors.



**Figure 1.** Main routes from Europe to the Middle East.

Source: *Trakia Economic Zone* <https://tez.bg/>

### Trakia Economic Zone – profile and dynamics of FDI

The establishment and evolution of greenfield industrial parks in the vicinity of Plovdiv–consolidated in 2013 under the unified brand Trakia Economic Zone (TEZ)–represent a notable example of decentralized regional policy. Initially launched as a private initiative by the local

construction holding Sienit, the project gradually transformed into a specific public–private partnership involving nine municipalities from the Plovdiv region (Mollov, 2023). Today, TEZ encompasses several industrial zones hosting over 200 domestic and international companies, with private investments exceeding €3 billion over roughly 25 years. The zones have generated more than 30,000 jobs (TIZ, 2022). While the business profile of TEZ is diverse, a significant share of enterprises belong to the automotive sector, producing components for the global automotive industry. Machinery and equipment manufacturing, metal product production, the food industry, and logistics also have strong representation, alongside specialized industries such as bicycle production. Medium-tech sectors dominate, although several high-tech enterprises are also present.

The creation of these greenfield industrial zones was entirely a local undertaking, independent of national regional policy. The private construction company behind the initiative developed an integrated business model designed to attract investment by offering a comprehensive range of services to potential investors. These include legal support for enterprises, collaboration with municipalities to ensure expedited administrative procedures, spatial planning and land regulation, fast-track design and construction of core technical infrastructure, and the development of production facilities.

In this decentralized partnership model, municipalities contribute primarily by promoting the region as a competitive investment destination, facilitating swift administrative services, assisting with spatial planning and infrastructure projects, enhancing educational and social services, and supporting the recruitment of local labor for businesses.

Officially formed in 2013, the Trakia Economic Zone is recognized as a reliable partner to both foreign and domestic investors in establishing new ventures or expanding existing ones (Table 1). Its success is the result of cooperation between SIENIT HOLDING AD, partners from Italy and Israel, and one of Bulgaria’s leading industrial enterprises, KCM 2000 AD. Legal consultancy is provided by Respect Consult Ltd., one of the country’s foremost law firms. TEZ unites five industrial zones–Maritsa, Rakovski, Kuklen, Plovdiv Industrial Park, and Innovation Park. Its achievements have earned Plovdiv a place among the top three in the “Strategy for Attracting Foreign Direct Investment” category in the European Cities of the Future 2018/2019 ranking.

In 2014, the Municipality of Plovdiv joined forces with eight other local municipalities and several associations to advance the TEZ project. The effective public–private partnership model enables the zone to maintain strong coordination with local and national authorities, educational institutions, associations, and the business community, ensuring the seamless implementation of investment projects:

- Investment Bulgaria Agency (IBA);
- 9 municipalities /Plovdiv, Asenovgrad, Kaloyanovo, Kuklen, Maritsa, Parvomay, Rakovski, Rodopi, Stamboliyski/;
- Regional administration Plovdiv;
- German Fraunhofer Institute – Europe's largest community for science and business;
- Respect Consult;
- Education-Industry Board with the Ministry of Education and Science Cluster Trakia Economic Zone and Industry Watch;
- Cluster Trakia Economic Zone;
- Information and Communication Technologies Cluster Plovdiv;
- Green Synergy Cluster;
- Srednogorie Industrial Cluster;
- Automotive Cluster Bulgaria;
- Executive Agency for the Promotion of Small and Medium-sized Enterprises;
- Bulgarian-Chinese Association for Business Development;
- American Chamber of Commerce;
- German-Bulgarian Chamber of Industry and Commerce;
- Franco-Bulgarian Chamber of Commerce;
- Chamber of Commerce and Industry – Plovdiv;



- Bulgarian-Scandinavian Chamber of Commerce;
- Greek Business Council in Bulgaria;
- The Association of Business Clusters in Bulgaria;
- Telerik Academy School.

**Table 1** Structure of FDI by sector. Source: *The Author, based on Trakia Economic Zone - <https://tez.bg/>.*

Sector	Investors
Production	Libherr (Germany), Schneider Electric (France), ABB (Switzerland), Mekalit Bulgaria
Automotive industry	Sensata (USA), Leoni (Germany), Magna (Canada) Malmar (Belgium), William Hughes (Great Britain), Willi Elbe Automotive Bulgaria
Logistics and distribution	DB Schenker, Kaufland, Lidl, PIMK
Food industry	Kaufland, Bella Bulgaria
High Technology/IT	Milara (USA), companies from the outsourcing sector

**Conclusions:**

- There is a clear diversification of the Trakia economic zone, characterized by a growing presence of enterprises in the field of information technology and automated production.
- There is increased interest in investments related to renewable energy sources and environmental technologies, which makes the TEZ a preferred location for so-called green investments.
- The developed transport and logistics infrastructure, combined with the availability of a qualified workforce and a scientific and educational base (including the universities in Plovdiv), are established as strategic advantages for sustainable development and the competitiveness of the area.

**Statistical Analysis**

The study was conducted on the 2021 database of three municipalities that are part of the Trakia economic zone: Plovdiv, Maritsa and Rakovski (Table 2). For each of them, relative shares (%) of:

- Foreign direct investment (FDI)
- Expenditures for acquisition of fixed assets (FIXED)
- Value added from economic activity were used

It analyzes how FDI and the costs of acquiring fixed assets (FIXED) affect the value added generated.

According to Todorova (2004), the calculation of the individual components in the analysis of the relationships between economic variables is carried out by applying standard statistical formulas for correlation analysis, allowing for quantitative measurement of the strength and direction of the dependence between the studied indicators.

A correlation analysis was performed using the Pearson coefficient (r), which measures the degree and direction of linear relationship between quantitative variables. The relationships are analyzed in pairs: FDI – Value Added (Figure 2); FDI – FIXED (Figure 3); FIXED – Value Added (Figure 4).



**Table 2** Economy and investments in 2021. *Source: IME based on NSI database.*

Municipalities	Added value	Amount of foreign direct investment	Expenses for acquisition of fixed assets
Plovdiv	74%	75%	68%
Maritza	8,1%	14%	8%
Rakovski	3,3%	6,1%	4,6%

It analyzes how FDI and the costs of acquiring fixed assets (FIXED) affect the value added generated.

A correlation analysis was performed using the Pearson coefficient ( $r$ ), which measures the degree and direction of linear relationship between quantitative variables. The relationships are analyzed in pairs: FDI – Value Added (Figure 2); FDI – FIXED (Figure 3); FIXED – Value Added (Figure 4).

➤ **FDI Analysis - Value Added**

**$r = 0.999$ , positive correlation**

Calculation of individual components:

Municipalities	Amount of foreign direct investment ( $x_i - \bar{x}$ )	Added value ( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ) · ( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ) <sup>2</sup>	( $y_i - \bar{y}$ ) <sup>2</sup>
Plovdiv	43,3	45,53	1971,882	1874,89	2072,98
Maritza	-17,7	-20,37	360,372	313,29	414,94
Rakovski	-25,6	-25,17	644,35	655,36	633,53
			<b>2976,35</b>	<b>2843,54</b>	<b>3121,45</b>

$\bar{x}$  and  $\bar{y}$  are average values;

$x_i$  - values for FDI;

$y_i$  - added value values.

Calculating averages:  $\bar{x} = \Sigma x : n = 95,1:3 = 31,7$ ;  $\bar{y} = \Sigma y : n = 85,4:3 = 28,46$

$r = \Sigma (x_i - \bar{x}) \cdot (y_i - \bar{y}) : \Sigma (x_i - \bar{x})^2 \cdot \Sigma (y_i - \bar{y})^2 = 2976,35 : \sqrt{2843,56 \cdot 3121,45} = 2976,35 : 53,32.55,87 = 2976,35:2978,98 = 0,999$

**$r = 0,999$**

➤ **FDI Analysis – FIXED**

**$r = 0.998$**



Calculation of individual components:

Municipalities	Amount of foreign direct investment ( $x_i - \bar{x}$ )	FIXED ( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ).( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ) <sup>2</sup>	( $y_i - \bar{y}$ ) <sup>2</sup>
Plovdiv	43,3	41,13	1780,93	1874,89	1691,68
Maritza	-17,7	-18,87	335,32	313,29	356,08
Rakovski	-25,6	-22,27	570,11	655,36	495,95
			<b>2686,36</b>	<b>2843,54</b>	<b>2543,71</b>

$\bar{x}$  and  $\bar{y}$  are average values;

$x_i$  - values for FDI;

$y_i$  - FIXED.

.

Calculating averages:  $\bar{x} = \Sigma x : n = 95,1:3 = 31,7$  ;  $\bar{y} = \Sigma y : n = 80,6:3 = 26,87$

$r = \Sigma (x_i - \bar{x}). (y_i - \bar{y}) : \Sigma (x_i - \bar{x})^2. \Sigma (y_i - \bar{y})^2 = 2686,36 : \sqrt{2843,54}. \sqrt{2543,71} = 2686,36 : 53,32.50,44 = 2686,36:2689,21 = 0,998$

**r = 0,998 → positive correlation**

➤ **Analysis of FIXED – Value Added**

**r = 0,999**

Calculation of individual components:

Municipalities	Added value ( $x_i - \bar{x}$ )	FIXED ( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ).( $y_i - \bar{y}$ )	( $x_i - \bar{x}$ ) <sup>2</sup>	( $y_i - \bar{y}$ ) <sup>2</sup>
Plovdiv	45,53	41,13	1872,65	2072,98	1691,68
Maritza	-20,37	-18,87	384,38	414,94	356,08
Rakovski	-25,17	-22,27	560,54	633,53	495,95
			<b>2817,57</b>	<b>3121,45</b>	<b>2543,71</b>



Calculating averages:  $\bar{x} = \Sigma x : n = 85,4:3 = 28,46$ ;  $\bar{y} = \Sigma y : n = 80,6:3 = 26,87$

$\bar{x}$  and  $\bar{y}$  are average values;

$x_i$  - added value values;

$y_i$  - FIXED.

$$r = \frac{\Sigma (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\Sigma (x_i - \bar{x})^2 \cdot \Sigma (y_i - \bar{y})^2}} = \frac{2817,57}{\sqrt{3121,53 \cdot 2543,71}} = \frac{2817,57}{55,87 \cdot 50,43} = \frac{2817,57}{2817,81} = 0,9999$$

**$r = 0,9999 \rightarrow$  positive linear relationship between value added and fixed assets.**

## RESULTS

The Plovdiv-Maritsa-Rakovski Center is characterized by a high level of economic development, driven mostly by the strong manufacturing industry in the peripheral municipalities and services in the Plovdiv Municipality. Over the past decade, it has experienced the fastest growth in added value among the 16 centers in the country. Unemployment is low in almost all municipalities, and employment is among the highest in the country. Wage growth is slower. The demographic picture in the center is relatively favorable compared to the rest of the country.

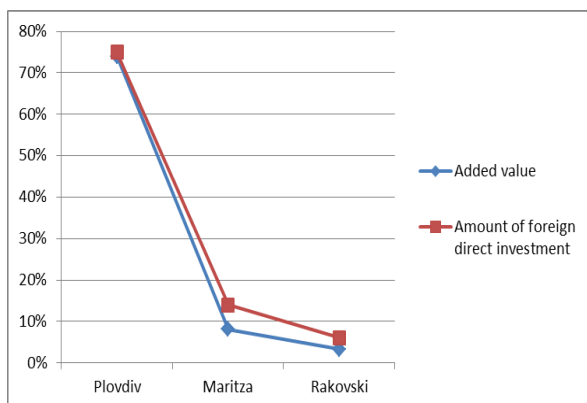
However, student achievement is low, and in places there are visible problems with illiteracy. With a production output of 20.1 billion BGN, or 36.4 thousand BGN per capita, in 2021 Plovdiv-Maritsa-Rakovski is the second largest economic center in the country. The growth of added value within the decade is the fastest among the 16 centers – 113%, mostly as a result of the accelerated development of industrial areas (Table 3).

**Table 3** Key indicators for the economic center "Plovdiv - Maritsa - Rakovski". *Source: IME based on NSI database.*

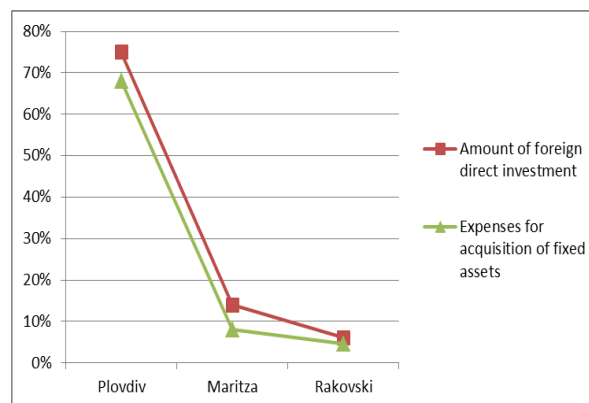
Key indicators for the economic center "Plovdiv - Maritsa - Rakovski"	
Production output (2021)	20.1 billion BGN
Economic growth (2012 – 2021)	113,4%
Export earnings (2021)	9156 million BGN
Amount of foreign direct investment (2021)	1893 million BGN
Expenses for acquisition of fixed assets (2021)	2109 million BGN

The present correlation analysis shows the interrelationships between FDI, the value of acquired FIXED and the value added created within the TEZ, providing quantitatively substantiated evidence of the economic efficiency of investments. In this case, foreign capital contributes directly to the growth of the regional economy.

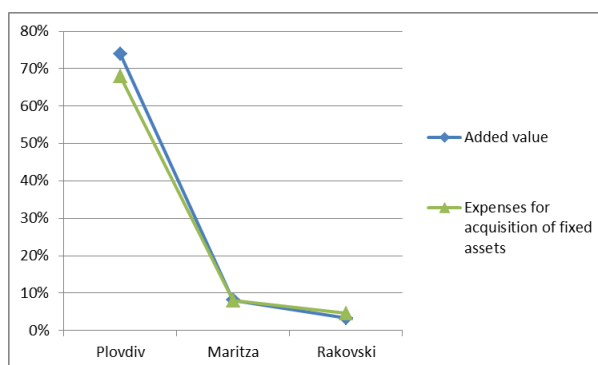




**Figure 2.** FDI – Value Added. Source: IME based on NSI database



**Figure 3.** FDI – FIXED. Source: IME based on NSI database



**Figure 4.** FIXED – Value Added. Source: IME based on NSI database

The amount of foreign direct investment accumulated in 2021 reached 1.89 billion euros, of which 75% is in Plovdiv, 14% - in Maritsa, and 6.1% - in Rakovski. Foreign capital is concentrated in industry (67%), real estate operations (14%) and trade, transport and tourism (9.8%). Expenditures for the acquisition of fixed assets in 2021 are relatively more evenly distributed, with 36% of the total BGN 2.1 billion in industry, 24% in trade, transport and tourism, 12% in real estate operations, and 9.9% in construction. And in this indicator of investment activity, the leader is the municipality of Plovdiv with 68%, followed by Maritsa with 8% and Rakovski, Rodopi and Asenovgrad with 4.6% each. Enterprises in the center realize the second highest export revenues in the country – over 9 billion leva, or 16.7 thousand leva per capita.

With a production output of 20.1 billion BGN, or 36.4 thousand BGN per capita, in 2021 Plovdiv-Maritsa-Rakovski is the second largest economic center in the country. The growth of added value within the decade is the fastest among the 16 centers – 113%, mostly as a result of the accelerated development of industrial areas (Figure 5). The largest employer in the center is St. George University Hospital with 2.7 thousand workers, followed by Liebherr-Hausgerete Maritsa with over 2 thousand employees, KCM and the transport company PIMK with 1.5 thousand employees each.

The leader in revenue for 2021 is Tabaco Trade with 930 million leva. According to the 2021 census data, the employment rate is among the highest – 65.1%, varying between 69.2% in Plovdiv and 48.5% in Krichim. The total number of employed people is 229 thousand, of which 144 thousand are in Plovdiv, 22 thousand in Asenovgrad, and 13 thousand in Rhodopes. Over the past 5 years, employment in the center has been shrinking, with the number of employed people decreasing by 1.3% compared to 2017. The employment structure closely follows that of value added, with 38% of workers in manufacturing, 19% in trade, and 6.9% each in transport and healthcare.

The use of correlation analysis shows that the Trakia Economic Zone successfully converts investments into economic development. Even in just one year (2021), there is a clear correlation between investments and the achieved added value.

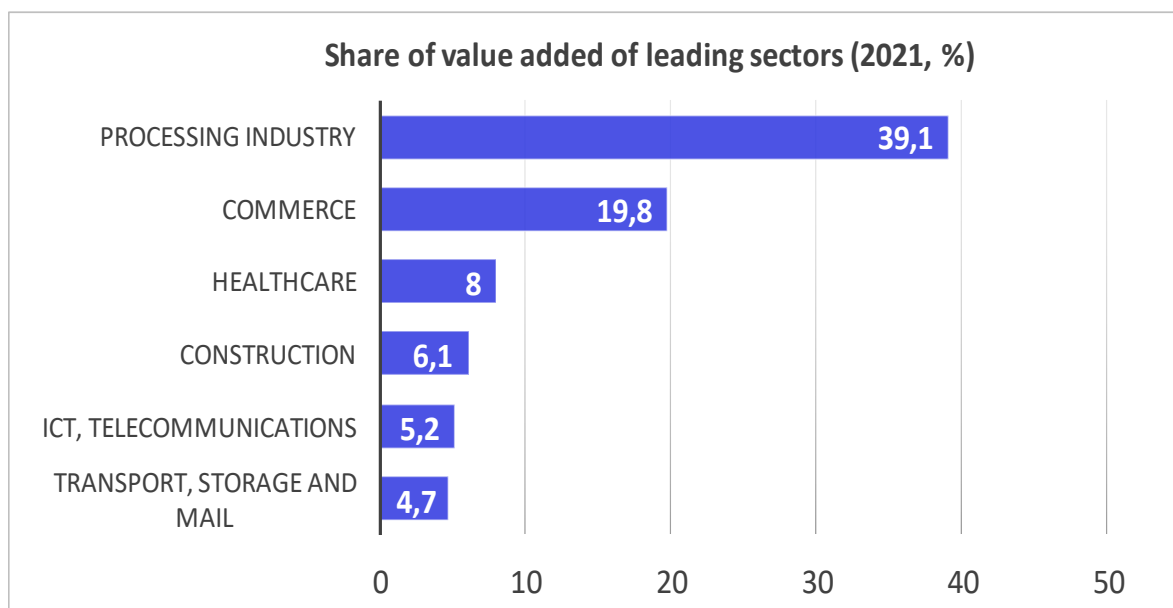


Figure 5. Share of value added of leading sectors (2021, %). Source: IME based on NSI database

## DISCUSSION

Foreign direct investment (FDI) policy in Bulgaria should adopt a selective and strategically targeted approach, prioritizing investments in sectors that offer high value-added potential, technological innovation, and strong export orientation. Such investments should be capable of integrating into local supply chains and creating sustainable linkages with small and medium-sized enterprises (SMEs), thereby amplifying positive spillover effects such as technological diffusion, managerial expertise transfer, and workforce upskilling. A well-calibrated FDI policy should also account for the changing global investment landscape, where competition for capital is intense, and investors increasingly value political stability, efficient administration, and predictable legal frameworks.

The systematic and transparent application of fiscal and financial incentives – whether in the form of tax breaks, accelerated depreciation schemes, or preferential access to infrastructure – can enhance investor confidence. Predictability in investment conditions is critical, as frequent legislative changes or inconsistent policy application can deter potential investors. Equally important is the reduction of non-financial barriers to investment, such as excessive bureaucracy, outdated regulatory procedures, and delays in legal dispute resolution. Ensuring effective property rights protection and improving the quality of administrative services will lower transaction costs for both foreign and domestic businesses, making Bulgaria a more competitive destination.

Infrastructure remains a cornerstone of FDI attractiveness. Accelerating the development of industrial zones in proximity to major regional centers with significant human resource potential can bridge existing gaps. Linking FDI projects with local SMEs can create a multiplier effect, increasing industrial competitiveness and generating employment, especially in emerging regional economies. The Trakia Economic Zone (TEZ) serves as a compelling case study in this regard, demonstrating how a well-structured public–private partnership can mobilize resources, reduce investment risks, and align the interests of multiple stakeholders.

Since its inception in 1996, TEZ has evolved into the largest and most sustainable industrial complex in Southeastern Europe, attracting over 200 companies, securing more than €3 billion in

investments, and generating upwards of 50,000 jobs. Its governance model – characterized by effective collaboration between local and national government, industry associations, academic institutions, and the private sector – illustrates the benefits of coordinated action. Furthermore, TEZ's sectoral diversification, including high-tech manufacturing, logistics, and renewable energy projects, highlights the importance of adaptability in investment strategies to meet evolving global economic trends.

## CONCLUSION

Foreign direct investment plays an important role in the economy of any country.

Progress in sustainable development requires more international investment in infrastructure, energy, water and waste management, environmental and climate protection, health and education, as well as investment in productive capacity to create jobs and increase incomes (Vranchev, 2020).

FDI and European Structural Funds are of great importance for financing important economic and social activities. However, they cannot be a “panacea” for all economic and social problems of Bulgaria if there are no clear objectives regarding economic priorities and a strategy for sustainable economic and social development, which is based on good European practices and the EU innovation strategy (Christova-Balkanska, 2012). The accumulation of FDI in Bulgaria influence positively the growth in GDP, boost ahead the development of the economy and restraint the leakage of labor force abroad in some years. FDI of quality and reinvestments make Bulgarian labor market much more attractive for young fellows.

- There is a distinct diversification of the Trakia economic zone, characterized by a growing presence of enterprises in the field of information technology and automated production.

- The developed transport and logistics infrastructure, combined with the availability of a qualified workforce and a scientific and educational base (including the universities in Plovdiv), are established as strategic advantages for sustainable development and the competitiveness of the area.

This report examines foreign direct investment in the Trakia economic zone, emphasizing the investment model – public-private partnership and its economic effects. FDI plays a key role in the development of the region, generating positive impacts on the economy, infrastructure and social structure.

Plovdiv is the place where the new Bulgarian industry is developing most rapidly and is an attractive point for foreign direct investment.

The Trakia Economic Zone represents a sustainable model for integrating FDI into the regional development of Bulgaria. The implementation of public-private partnership, cluster organization and individualized investment services leads to many benefits for both investors and the local economy. The TEZ is being established as evidence of the applicability of territorially oriented strategies for attracting FDI, emphasizing the importance of targeted institutional frameworks, adequate infrastructure and educational symbiosis between business and academic institutions.

Foreign direct investment remains a central pillar of economic development for Bulgaria, with the potential to drive industrial modernization, enhance productivity, and support regional development. To fully harness these benefits, a coherent strategy that combines targeted sectoral priorities, infrastructure development, and institutional reform is essential. Sustainable progress requires not only attracting new investments but also ensuring the retention and reinvestment of existing capital through stable policy frameworks and supportive business ecosystems.

The analysis of TEZ underscores several critical success factors: a diversified industrial base capable of absorbing and applying new technologies; a strong logistics and transport network; an available and qualified labor force supported by higher education institutions; and a governance model based on public-private partnerships that align the interests of investors with local and regional development goals. These elements have positioned TEZ as a benchmark for other regions aiming to integrate FDI into their economic growth strategies.



The strategic challenge for Bulgaria is to replicate and adapt this model to other regions, thereby reducing territorial disparities and promoting balanced national development. This entails expanding industrial zone infrastructure, fostering industry–academia collaboration to meet evolving labor market demands, and ensuring policy continuity that builds long-term investor trust.

In conclusion, TEZ demonstrates that territorially focused investment strategies – grounded in strong institutional frameworks, modern infrastructure, and active stakeholder collaboration – can generate substantial economic, social, and technological benefits. When supported by consistent policy and regional planning, such initiatives can serve as catalysts for sustainable development, enhancing Bulgaria’s position in the global investment landscape and ensuring long-term competitiveness in an increasingly interconnected economy.

#### ***Declaration by Authors***

**Ethical Approval:** Approved

**Acknowledgement:** None

**Source of Funding:** None

**Conflict of Interest:** The authors declare no conflict of interest.

#### **REFERENCES**

- Abamu, E. B. (2019). Introducing Investment Promotion: A Marketing Approach to Attracting Foreign Direct Investment. <https://doi.org/10.5539/ijms.v11n4p91>
- Christova-Balkanska, I. (2012). Opportunities for Increasing the Innovation Potential of Bulgaria concerning Foreign Direct Investments and European Structural Funds. *Economic studies* 3:95-107
- Concept for the development of industrial parks and zones 2024-2028. <https://www.mi.government.bg/>
- Decree No. 2242 on free duty-free zones.
- Dissertation on the Theory of Foreign Direct Investment. (1996). „The Theory of Multinational Enterprises: Selected Scientific Papers of Alan M. Rugman, vol. 75.
- Dunning J. H., Rugman, Alan M. (1996). „The Influence of Hymer’s Dissertation on the Theory of Foreign Direct Investment”, „The Theory of Multinational Enterprises: Selected Scientific Papers of Alan M. Rugman, vol. 75.
- Economic Yearbook of the Plovdiv Region. (2019)
- Ganchev, D. (2017). Foreign Direct Investment and Regional Economic Performance in Bulgaria. *Thracian Scientific Journal*
- Ganeva-Simeonova, R., Vassilev, A., Ganev, Kaloyan, Dimitrov, L. (2019) Medium-term and long-term forecasts for the development of the labor market in Bulgaria. Employment and imbalances in the labor market, labor supply factors (2008 - 2034).
- Harrod, R. F. (1959). Domar and dynamic economics. *Economic Journal*. 69: 451-64.
- Hymer, Stephen. (1970). „The Efficiency (Contradictions) of Multinational Corporations”, *The American Economic Review*, vol. 60, No. 2.
- Institute for Market Economy, 2023. "Economic Centers in Bulgaria - 2023". <https://invest.plovdiv.bg/>
- Kindleberger, Charles P. (1969). „American Business Abroad: Six Lectures on Direct Investment”, New Haven and London, Yale University Press.



Milkova, K. (2016). Geographical analysis of foreign direct investment in Bulgaria in the context of regional development. Abstract of dissertation.

Mollov, Y. (2023). Decentralized regional policy – the example of Plovdiv. *National scientific conference with international participation 2022*. 21 – 22 November 2022, Sofia

Petkova, E. (2016). Competitive advantages of companies and imperfect competition in microeconomic theories of foreign direct investment.

International scientific conference "Economic welfare through knowledge sharing", Academic Publishing House "Tsenov", Svishtov, ISBN: 978-954-23-1185-0.  
<http://hdl.handle.net/10610/3004>

Strategy for the Development of Industrial Zones 2015. <https://www.strategy.bg/>

Todorova, S. (2004). Statistics in economics and business. Sofia

Vranchev, K. (2020). Influence and effects of foreign direct investment on economic growth.

Zhelev, P. & Kusainova, A. (2024). Bulgaria's Experience in Attracting Foreign Direct Investment - Lessons for Developing Economies. University of National and World Economy, Sofia, Bulgaria <https://doi.org/10.17059/ekon.reg.2024-1-21>

**How to cite this article:**

Gavrilova, O. (2025). Foreign Direct Investments in Trakia Economic Zone: Models and Economic Effects. *International Journal of Digital Research*, E-ISSN: 3033-179X, Volume 1 (3): 21-34  
<https://doi.org/10.63711/ijdr.net20250302>

\*\*\*\*\*



# Influence of Social Networks on the Subjective Feelings of Loneliness in Adolescents and Youth

Teodor Gergov<sup>1</sup>, Tsvetelina Hadzhieva<sup>2</sup>

<sup>1</sup>Associate Professor, PhD, <sup>2</sup>Chief Assistant Professor, PhD

<sup>1,2</sup> Department of Psychology, Faculty of Philosophy, SWU “Neofit Rilski”, Blagoevgrad, Bulgaria.

<sup>1</sup> ORCID ID: 0000-0001-9857-5774, <sup>2</sup> ORCID ID: 0000-0001-7856-9430

Corresponding Author: Tsvetelina Hadzhieva, E-mail: [cveti\\_hadjieva@swu.bg](mailto:cveti_hadjieva@swu.bg)

<https://doi.org/10.63711/ijdr.net20250303>

## ABSTRACT

Social networks have established themselves as a new way of communication, largely transforming the traditional interaction between people, shifting the focus from direct, live communication to the fast and convenient online analogue of social platforms. This, in turn, has led to several changes that are reflected in personal and social functioning. One of the phenomena that modern researchers are examining in this regard is the subjective feeling of loneliness in young people, which is a negative consequence of excessive social network use. This is precisely the motive for exploring this issue in this article – how social networks affect the subjective feeling of loneliness in adolescents and young people.

The present study underscores the complex relationship between social media usage and feelings of loneliness among young people. Adolescents were found to be more susceptible to the negative impacts of social networks, manifesting in higher levels of loneliness compared to young adults.

**Keywords:** *Social networks, Information channels, Loneliness, Adolescents, Young people.*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

It is extremely noticeable how over the past few decades social networks have caused avalanche-like changes in all spheres of public life, affecting representatives of almost all age groups, especially children and adolescents. Social networks, as an already established communication channel, have led to changes in the way and quality of communication between people, access to information, and sharing of experience. They have lowered the boundaries of communication in terms of time, place, and language barrier, while at the same time allowing largely uncontrolled access to all kinds of information.

The development of social networks has been a long process, marked by the gradual rise of communications and technology. The first online platforms were created in the 1990s, allowing users to create personal profiles and communicate in real time in so-called "virtual chat rooms", sharing personal information and creating a friendly online community.

Social desirability is strongly present in human nature, expressed in the desire for a person to be liked and accepted by others in society. This tendency is especially characteristic of the period of adolescence, where the development of identity is at its most acute. Social networks provide an opportunity for a quick and measurable way of social status. Their fear, likes, and comments on publications validate this need and strengthen dependence on social networks. This is a digital analogue that determines the level of social value, having a direct and significant impact on the emotional state and self-esteem. Positive evaluation in social networks is not only a prerequisite for pleasant experiences, but also forms behavior that stimulates more frequent use of social networks (Sherman et al., 2016).

Another characteristic of social networks is that they allow for selective representation of the personality, which in most cases can lead to cognitive dissonance, i.e., to a blurring of the real and virtual image of the personality. This, in turn, can have its negative effects, expressed in tension, anxiety, and even depressive states. A study shows that adolescents who compulsively seek approval on social networks are at a much higher risk of developing anxiety and depression (Sherman *et al.*, 2016).

Excessive use of social networks has a rather negative impact, which is expressed in all spheres of people's lives, with the most vulnerable group being children, adolescents, and young people. Research suggests that daily use of social media, especially among young people, leads to higher levels of anxiety and depression (Heffer, Good, *et al.*, 2019; Twenge, Martin, & Campbell, 2018).

Excessive use of social media leads to so-called fragmented attention, which is the inability to maintain deep concentration due to constant switching between different stimuli, which in turn has an adverse effect on long-term memory and the ability to think critically. Studies in this regard show that frequent switching from one platform to another (Facebook, Instagram, TikTok) leads to a decrease in cognitive performance while at the same time increasing stress levels (Rosen *et al.*, 2013; Lin *et al.*, 2017). An interesting fact has also been established, in which even the mere presence of a technical device near a person reduces cognitive capacity, since the mere expectation of a notification "reserves" part of the attention (Ward *et al.*, 2017).

On the other hand, this so-called cognitive intolerance is associated with negative internal experiences and avoidance, which creates a real risk of psychological problems such as anxiety and depression. "Cognitive intolerance refers to a circumstance in which an individual experiences difficulty accepting their internal experiences, which leads to the avoidance or prevention of unpleasant thoughts, feelings, and emotions" (Hayes, Strosahl, & Wilson, 2004, p. 163).

Cognitive intolerance can increase feelings of insecurity and isolation to avoid unpleasant thoughts and emotions associated with social media, such as fear of negative evaluation or comparison to others. This creates a vicious cycle in which social media becomes a source of stress and isolation rather than a means of connection and support.

Numerous studies have shown that excessive use of social media negatively affects cognitive functioning, resulting in decreased concentration, superficial processing of information, and increased levels of impulsivity. Social media generates constant exposure to short and fragmented content, which in turn hinders the ability to think deeply and critically. Social media not only transforms

memory and decision-making functions, but also restricts cognitive flexibility (Carr, 2010; Sparrow, Liu, & Wegner, 2011; Meshi, Tamir, & Heekeren, 2015; Ophir, Nass, & Wagner, 2009; Rosen, Carrier, & Cheever, 2013).

The constant overexposure of “idealized” images on social networks is also a predictor of low self-esteem and dissatisfaction in young people, who are exposed to psychological pressure from the networks to “meet” certain standards. The unrealistic body image thus instilled is internalized into an externally imposed ideal of a beautiful body, which the young person compulsively begins to strive to achieve (Appel *et al.*, 2016; Hadjiveva, 2023; Grogan, 2008; Zaccagni *et al.*, 2014).

Research conducted in this regard indicates that this process of external internalization is a major factor in the development of negative body image and is very often a predictor of the development of eating disorders (Thompson *et al.*, 1999).

Also, some other studies have found that constant digital pressure and the associated social comparisons significantly increase the risk of developing anorexia, bulimia, and other unhealthy eating behaviors (Homan & Tylka, 2014).

From this, we can conclude that the mental perception of the body, formed in the context of social networks, is often a real prerequisite for the development of eating disorders, combining psychological, social, and cultural factors.

Social networks are based on the principle of so-called unpredictable rewards, which is the main mechanism for the establishment of addictive behavior. This effect (operant conditioning) was described as far back as 1963 by Skinner (1963) as a result of his experiment (animals continue to press a lever, although the expected reward in the form of food is unpredictable) (Skinner, 1963). Compulsive interaction with social networks, in terms of notifications, likes, comments, etc., appears in the form of a reward, activating the release of dopamine and, accordingly, the experience of pleasure. This, in turn, leads to higher levels of impulsivity and low levels of concentration. In terms of platforms like Facebook, Instagram, and TikTok, which have algorithms designed to encourage addictive behaviors like gambling, research suggests that these algorithms provide users with personalized content that leads to increased dopamine levels, similar to gambling and drug addiction (Andreassen *et al.*, 2012; Balcerowska *et al.*, 2020; Schultz, 2016; Volkow, Wise, & Baler, 2019).

Also, technology companies are deliberately designing the platforms themselves to prolong the time users spend on them. This excessive time creates another negative prerequisite that prevents young people from developing empathy and social resilience, as they avoid facing real conflicts, serious conversations, and deep emotional connections. Their focus is on the likes they generate under their posts, short reactions, and above all on the visual image, which at times is even compulsively pursued by adolescents. The constant need for external approval in adolescents leads to anxiety, low self-esteem, and a very strong need for feedback, especially positive feedback (Turkle, 2012; Zuboff, 2019; Alter, 2020).

### **Social networks and the feeling of loneliness**

Loneliness among young people has been the subject of extensive research in recent years, with a particular focus on the role of social networks in this process. A number of studies have found that the level and quality of interactions in the digital environment can have both positive and negative effects on psycho-emotional well-being.

Initially, the purpose of social networks is to connect people, but despite this, research shows that excessive use of these platforms can cause feelings of loneliness and isolation. People who use social



networks excessively develop higher levels of loneliness and isolation. How adolescents form their identity also changes, as a result of which they feel lonelier. In this regard, the formation of the self during adolescence is a critical period during which young people acquire an understanding of themselves through interactions with others, verbal, and non-verbal communication. Communication of young people with older people is of key importance for the transmission of social experience. In social inheritance, young people acquire knowledge from experience, i.e., all the values acquired during the adult's life path. But in the online environment, the adolescent creates a selective profile for himself, which corresponds to the requirements of socially desirable acceptance, which is standardized on social platforms. The paradox observed in this regard, as deduced by Turkle, is “alone together”, i.e., people are physically alone, but digitally connected through social networks, which create an illusion of closeness, whose communication is fragmented, superficial, often devoid of content, and does not satisfy the original human need for emotional connection. And ultimately, high levels of loneliness are observed, despite a strong online presence (Gergov, 2010; Turkle, 2012).

The brief overview of communication as an initially significant and connecting process in real time, which develops personal and social skills necessary for the integration and adaptation of the personality in the dynamics of socio-economic processes. Communication is the cornerstone of social inheritance, which is a key factor in the transmission of experience from the older generation to the younger. Communication is, in principle, one of the basic human needs, which is originally associated with the emergence of man and is a key factor in the establishment and maintenance of psycho-physiological health. Communication is a major source of health, which creates conditions for social interaction, emotional support, and resilience (Adler, 2007). Naturally, on the other hand, the lack of effective communication and social connectedness leads to health problems and mental disorders.

The need for communication is inherently embedded in human nature. Social connectedness, based on effective communication in which the individual feels emotionally supported, is the basis for achieving optimal health and emotional satisfaction, which are initially predictors of higher success in one's overall life plan. Deficient social interactions, in turn, lead to isolation, which in turn creates a greater risk of developing anxiety and depressive disorders, as well as physical health problems (Baumeister & Leary, 2017; Cacioppo & Cacioppo, 2014).

A study conducted in this regard presents eloquent results indicating that social isolation and deficient communication lead to a higher risk of mortality in young people (Holt-Lunstad, Smith & Layton, 2010).

Another study conducted among adolescents during COVID-19 found that social isolation and limited verbal communication led to higher levels of depression and anxiety in adolescents. Therefore, social interactions are of utmost importance, even in conditions of distance, for maintaining mental health in young people (Loades *et al.*, 2020).

Also, regarding online communication, research shows that effective, satisfying, and supportive communication, albeit in the online space, leads to more objective, positive self-evaluation and a lower risk of mental health problems (Lerner, 2015).

According to Keles, McCrae, and Grealish (2020), social media has the potential to reduce feelings of loneliness by facilitating social interaction and maintaining connections, particularly for people who are physically restricted from social settings. However, research suggests that excessive use, especially when interactions are superficial and lack emotional depth, can have the opposite effect – contributing to higher levels of loneliness.



There has been a wealth of empirical research on the impact of social media on loneliness in adolescents and young adults, with most suggesting that the relationship is complex and often bidirectional. Excessive use of social media has been linked to a higher risk of feeling isolated and lonely among young people. Researchers argue that “when interactions become superficial and focus only on the quantity rather than the quality of communication, this leads to increased feelings of isolation, especially among adolescents who are still forming their social identities” (Keles *et al.*, 2020, p. 9).

Caplan's (2002) research suggests that social networking sites can cause feelings of loneliness when users use the platforms as a substitute for real-life social relationships. He argues that “when online interactions are superficial and do not lead to deep and satisfying contacts, this increases feelings of isolation” (Caplan, 2002, p. 70).

Another study conducted by Lee *et al.* (2016) found that adolescents who reported spending more time on social media reported greater feelings of loneliness and isolation. They emphasized that “this relationship was more pronounced among young people who used social media as a substitute for real-life interpersonal relationships, compensating for their need for emotional connection” (Lee *et al.*, 2016, p. 120).

Research conducted by Hoffman *et al.* (2017) also supports the idea that in youth and adolescents, time spent on social media is associated with higher levels of social anxiety and loneliness, often due to a lack of satisfying and authentic social connections. They note that “additional hours spent online, without the presence of deep communication, may activate neural pathways that reinforce feelings of isolation and alienation” (Hoffman *et al.*, 2017, p. 135).

Another study by Cacioppo and Patrick (2008) found that prolonged social isolation is associated with changes in motivational and emotional domains that increase feelings of loneliness. Their study emphasizes the importance of quality interpersonal relationships for mental health and the opposite effect when these relationships are absent or insufficient.

Overall, scientific data establishes that virtual social networks are a two-sided factor - with balanced use, they create a sense of belonging, but with excessive use and devoid of real emotional connections, they lead to an increased feeling of social isolation and loneliness.

## **MATERIALS & METHODS**

Methodological tools were used to conduct this study: Bergen Social Media Addiction Scale (BSMAS) and the UCLA Loneliness Scale Test Scale.

The BSMAS was designed as a short, reliable, and valid tool for assessing social media addiction. It was developed by Andreassen *et al.* (2017) as part of broader research on digital addiction. Each question is rated on a 5-point Likert scale (from 1: “never/not yet” to 5: “every day/very often”).

Loneliness Scale is one of the most widely used and validated instruments for measuring feelings of loneliness. In its original development and subsequent studies, the internal reliability coefficient ( $\alpha$ -coefficient) typically ranges between 0.85 and 0.91, indicating very good reliability and internal consistency of the scale (Russell, 1996).

The study was conducted in the period April - July, 2025. Its implementation was on a voluntary and anonymous basis, directly and through the online form of the questionnaires. 279 people participated, of whom 156 (51.7%) were women and 123 (48.3%) were men. In terms of age, the



respondents cover two adjacent age periods - adolescents (15-19 years) - 146 people (56.7%) and young people (20-30 years) - 133 people (43.3%).

The following hypotheses were raised:

1. It is assumed that there is a positive correlation between time spent on social networks and feelings of loneliness in adolescents and young adults.
2. It is assumed that adolescents are lonelier compared to young adults.
3. It is assumed that women are lonelier than men.

The data collected from the test methodologies were processed and analyzed using the statistical program SPSS 23. The statistical methods for processing the data that were applied were the T-test and correlation analysis.

## RESULTS

*Table 1. Age differences in mean loneliness scores.*

Group	Mean	SD	t-value	df	p-value
15-19 (adolescents)	5.73	1.37	t=8.85	279	<0.001
20-30 (youth)	4.49	0.98			

Analysis of the results of the study shows that age has a significant impact on the feeling of loneliness ( $t = 8.85, p < 0.001$ ). Adolescents (15–19 years) experience a greater feeling of loneliness ( $M = 5.73$ ) compared to young people (20–30 years)  $M = 4.49$ . These results support the second hypothesis. Adolescents are more sensitive to social factors that can provoke a feeling of isolation and loneliness, due to the transient nature of this phase and significant social changes. This curve of social adaptation requires specific support strategies to prevent long-term negative impacts on mental health. According to research by Steinberg (2014), it is during adolescence that significant changes occur in perceptions of social support and feelings of isolation, and during this phase, it is necessary to introduce interventions to support emotional adaptation.

*Table 2. Gender differences in mean loneliness scores*

Group	Mean	SD	t-value	df	p-value
Women	6.14	2.38	t = 9.10	279	<0.001
Men	4.27	1.96			

The results of the T-test indicate statistically significant gender differences ( $t = 9.10, p < 0.001$ ), with women feeling lonelier ( $M = 6.14$ ) compared to men ( $M = 4.27$ ). This supports the third hypothesis raised, that women are lonelier, probably due to their more emotional nature and tendency to withdraw into themselves. Traditionally, the fairer sex experiences events more deeply and

emotionally colors what is happening. This, in turn, suggests the need to provide psychological support to women as an effective measure to improve their mental well-being.

*Table 3. Correlation between time spent on social networks and loneliness.*

Group	Correlation coefficient (r)	Significance (p-value)
Teenagers (15-19 years old)	0.70	$p < 0.001$
Youth (20-30 years old)	0.45	$p < 0.01$

The analysis of the results of the correlation analysis shows a higher correlation coefficient ( $r=0.70$ ) in adolescents, which means that there is a significant direct proportional relationship between the time spent on social networks and the feeling of loneliness. This suggests that in this age group, increasing time spent on social media has a strong, statistically significant relationship with increasing feelings of loneliness.

Young people also show a positive correlation, but it is weaker ( $r=0.45$ ) compared to adolescents, but still significant.

These results support the first hypothesis, of a significant positive correlation between time spent on social media and feelings of loneliness. The trend is more pronounced among adolescents, which highlights the peculiarities of the perception and impact of social media at an earlier age.

The results of this study provide us with the opportunity and support for a more extensive and in-depth future study in this regard, which would be supported by a larger volume of empirical material and would explore more statistically significant patterns that would contribute to enriching the scientific fund on this current contemporary topic.

## DISCUSSION

Consistent findings from recent research indicate that excessive use of social media platforms is linked to increased feelings of loneliness and social isolation among adolescents and young adults (Huang, 2017; Keles et al., 2020). Studies such as those conducted by Primack et al. (2017) suggest that the content users consume and produce online can amplify dissatisfaction and widen social gaps, thereby negatively impacting mental well-being.

Furthermore, research by Elhai et al. (2018) highlights that overuse of social networking sites can substitute real-life social interactions, leading to heightened loneliness and alienation. This issue is particularly critical during the formative years when social development and identity formation are at their peak. While these platforms offer valuable opportunities for connection, the risk of misuse and dependency remains a significant concern that calls for targeted prevention and educational strategies.

In light of these findings, it becomes clear that there is a pressing need for systematic interventions that promote balanced engagement with social media, along with skills to critically assess digital content and foster meaningful offline relationships. Future research should continue exploring these connections and seek effective approaches to improve mental health and social inclusion among youth.



In previous studies related to the current research, the results indicate that social isolation and feelings of loneliness are strongly connected, with social networks capable of both amplifying and reducing these feelings depending on how they are used (Cacioppo & Cacioppo, 2018; Twenge et al., 2018). Additionally, higher activity on social networks is associated with greater feelings of loneliness and depression among adolescents (Keles et al., 2020; Laschinger & Fida, 2014).

Undoubtedly, existing scientific research confirms that excessive use of social networks is linked to increased feelings of loneliness and social isolation among adolescents and young people. These findings show that high levels of online social activity often lead to the opposite of the expected sense of connectedness and support, while simultaneously increasing feelings of abandonment and loneliness. Conversely, healthier and more balanced use of social media can reduce these negative effects and support social well-being. To mitigate these adverse impacts, it is necessary to develop effective educational programs and strategies for responsible use of digital platforms among young people.

## CONCLUSION

The theoretical overview and empirical research conducted in this study confirm the significant influence of social networks on the mental functioning of adolescents and young people. Their impact is multifaceted, affecting not only social behavior and self-perception but also emotional well-being and cognitive functioning. The data obtained clearly show that loneliness is more pronounced in adolescents than in young adults, which is understandable given the transitional nature of adolescence and the heightened need for affiliation typical of this developmental stage. In this sensitive period, young people are simultaneously seeking autonomy and striving for social acceptance, making them more vulnerable to the negative effects of excessive online interaction.

The finding that women report higher levels of loneliness than men aligns with previous research, suggesting that gender-related differences in emotional processing, social expectations, and coping mechanisms play a decisive role. Women's stronger tendency toward emotional introspection and relational sensitivity may increase their susceptibility to feelings of isolation, especially in the absence of meaningful social support.

The strong positive correlation identified between the time spent on social networks and loneliness – particularly pronounced among adolescents – highlights the need for timely preventive strategies. These should not aim to demonize technology but rather to promote balanced, conscious, and purposeful use of digital platforms. Educational programs fostering media literacy, emotional resilience, and critical thinking about online content could mitigate the risk of substituting superficial digital connections for genuine interpersonal relationships.

From a broader perspective, the results underline the dual nature of social networks: while they offer unprecedented opportunities for connection, self-expression, and information exchange, their misuse can exacerbate emotional vulnerability, impair real-life social skills, and deepen feelings of alienation. Addressing this challenge requires a coordinated effort among educators, psychologists, policymakers, and families to encourage healthy digital habits, promote offline social engagement, and provide support systems that address the psychological needs of young people.

Future research should focus on longitudinal and cross-cultural studies to better understand the evolving relationship between social media use and loneliness in the context of rapidly changing



digital trends. Such studies could also examine the protective factors that enable some young people to use social networks without experiencing detrimental effects. By adopting a proactive and evidence-based approach, society can harness the positive potential of social networks while minimizing their risks, ultimately fostering healthier, more resilient, and socially connected generations.

### ***Declaration by Authors***

**Ethical Approval:** Approved

**Acknowledgement:** None

**Source of Funding:** None

**Conflict of Interest:** The authors declare no conflict of interests.

## **REFERENCES**

- Adler, A. *Humanities* (2007). Sofia: Publishing House "Health and Happiness".
- Hadzhieva, Ts. (2023). Research on the psychological characteristics of children and adolescents. Blagoevgrad: University of Applied Sciences "N. Rilski".
- Alter, S. (2020). Making sense of smartness in the context of smart devices and smart systems. *Information Systems Frontiers*, 22(2), 381-393.
- Andreassen, CS, Pallesen, S., & Griffiths, MD (2017). The relationship between addictive use of social media, narcissism, and self-esteem: Findings from a large national survey. *Addictive Behaviors*, 64, 287-293.
- Andreassen, CS, Torsheim, T., Brunborg, GS, & Pallesen, S. (2012). Development of a Facebook addiction scale. *Psychological reports*, 110(2), 501-517.
- Appel, H., Gerlach, AL, & Crusius, J. (2016). The interplay between Facebook use, social comparison, envy, and depression. *Current opinion in psychology*, 9, 44-49.
- Balcerowska, JM, Bereznowski, P., Biernatowska, A., Atroszko, PA, Pallesen S., & Andreassen, CS (2020). Is it meaningful this distinguish between Facebook addiction and social networking websites addiction? Psychometric analysis of Facebook addiction and social networking websites addiction scales. *Current Psychology*, 1-14.
- Baumeister, RF, & Leary, MR (2017). The need this belong: Desire for interpersonal attachments as a fundamental human motivation. *Interpersonal development*, 57-89.
- Cacioppo, JT, & Cacioppo, S. (2014). Social relationships and health: The toxic effects of perceived social isolation. *Social and personality psychology compass*, 8(2), 58-72.
- Cacioppo, JT, & Patrick, W. (2008). *Loneliness: Human nature and the need for social connection*. WW Norton & Company.
- Cacioppo, J. T., & Cacioppo, S. (2018). The growing problem of loneliness. *The Lancet*, 391(10119), 426.
- Caplan, SE (2002). Problematic Internet use and psychosocial well-being: development of a theory-based cognitive-behavioral measurement instrument. *Computers in human behavior*, 18(5), 553-575.
- Carr, N. (2010). *The Shallows: What The Internet Is Doing this Our Brains*. WW Norton & Company.
- Elhai, J. D., Levine, J. C., & Hall, B. J. (2018). Non-Social, Social, and Problematic Internet Use in Adolescents: The Role of Social Anxiety and Loneliness. *Psychiatry Research*, 266, 344-350. <https://doi.org/10.1016/j.psychres.2018.03.014>



- Gergov, T., Motivation for affiliation in the third age. Collection. Psychology - traditions and perspectives. Edited by I. Asenova, St. Stoyanova, University Institute "Neofit Rilski", Blagoevgrad, II volume, pp. 321-328, ISSN 1314-9792, 2010.
- Grogan, G. (2008). *Psalms*. Wm. B. Eerdmans Publishing.
- Hayes, SC, Strosahl, K., Wilson, KG, Bissett, RT, Pistorello, J., Toarmino, D., & McCurry, SM (2004). Measuring experiential avoidance: A preliminary test of a working model. *The psychological record*, 54(4), 553-578.
- Heffer, T., Good, M., Daly, O., MacDonell, E., & Willoughby, T. (2019). The longitudinal association between social media use and depressive symptoms among adolescents and young adults: An empirical reply this Twenge and al (2018). *Clinical Psychological Science*, 7(3), 462-470.
- Hoffman, PF, Abbot, DS, Ashkenazy, Y., Benn, DI, Brocks, JJ, Cohen, PA, & Warren, SG (2017). Snowball Earth climate dynamics and Cryogenic geology-geobiology. *Science Advances*, 3(11), e1600983.
- Holt-Lunstad, J., Smith, TB, & Layton, JB (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS medicine*, 7 (7), e1000316.
- Homan KJ, & Tylka TL (2014). Appearance-based exercise motivation moderates the relationship between exercise frequency and positive body image. *Body image*, 11(2), 101-108.
- Huang, C. (2017). Time spent on social network sites and psychological well-being: A meta-analysis. *Cyberpsychology, Behavior, and Social Networking*, 20(6), 346-354. <https://doi.org/10.1089/cyber.2016.0758>
- Keles, B., McCrae, N., & Grealish, A. (2020). A systematic review: The influence of social media on depression, anxiety, and psychological distress in adolescents. *International Journal of Adolescence and Youth*, 25(1), 79-93. <https://doi.org/10.1080/02673843.2020.1721711>
- Laschinger, H. K. S., & Fida, R. (2014). A time-lagged analysis of the effect of authentic leadership on workplace bullying, burnout, and occupational turnover intentions. *European Journal of work and organizational psychology*, 23(5), 739-753.
- Lee, DE, Ayoub, N., & Agrawal, DK (2016). Mesenchymal stem cells and cutaneous wound healing: Novel methods that increase cell delivery and therapeutic efficacy. *Stem cell research & therapy*, 7 (1), 37.
- Lerner, RM, Lerner, JV, P. Bowers, E., & John Geldhof, G. (2015). Positive youth development and relational-developmental systems. *Handbook of child psychology and developmental science*, 1-45.
- Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H., & Zhao, W. (2017). A survey/her Internet of Things: Architecture, enabling technology, security and privacy, and applications. *IEEE internet of things journal*, 4 (5), 1125-1142.
- Loades, ME, Chatburn, E., Higson-Sweeney, N., Reynolds, S., Shafran, R., Brigden, A., & Crawley, E. (2020). Rapid systematic review: the impact of social isolation and loneliness him/her the mental health of children and adolescents in the context of COVID-19. *Journal of the American Academy of Child & Adolescent Psychiatry*, 59 (11), 1218-1239.
- Meshi D., Tamir DI, & Heekeren HR (2015). The emerging neuroscience of social media. *Trends in Cognitive Sciences*, 19 (12), 771-782.
- Ophir E., Nass C., & Wagner A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences*, 106 (37), 15583-15587.
- Primack, B. A., Shensa, A., Sidani, J. E., Whaite, E. O., Lin, L., Rosen, D., Colditz, J. B., Radovic, A., & Miller, E. (2017). Social Media Use and Perceived Social Isolation Among Young Adults in the U.S. *American Journal of Preventive Medicine*, 53(1), 1-8. <https://doi.org/10.1016/j.amepre.2017.01.010>
-

- Rosen, LD, Carrier, LM, & Cheever, NA (2013). Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior*, 29 (3), 948-958.
- Rosen, LD, Whaling, K., Carrier, LM, Cheever, NA, & Rökkum, J. (2013). The media and technology usage and attitudes scale: An empirical investigation. *Computers in human behavior*, 29 (6), 2501-2511.
- Russell, DW (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of personality assessment*, 66 (1), 20-40.
- Schultz, W. (2016). Dopamine reward prediction error coding. *Dialogues in Clinical Neuroscience*, 18 (1), 23-32.
- Sherman, LE, Payton, AA, Hernandez, LM, Greenfield, PM, & Dapretto, M. (2016). The power of the like in adolescence: Effects of peer influence on her neural and behavioral responses to this social media. *Psychological science*, 27 (7), 1027-1035.
- Skinner, B.F. (1963). Operant behavior. *American psychologist*, 18 (8), 503.
- Sparrow, B., Liu, J., & Wegner, DM (2011). Google affects him/her memory: Cognitive consequences of having information at our fingertips. *Science*, 333 (6043), 776-778.
- Thompson, JK, Coovert, MD, & Stormer, SM (1999). Body image, social comparison, and eating disturbance: A covariance structure modeling investigation. *International Journal of Eating Disorders*, 26 (1), 43-51.
- Turkle, S. (2012). In Constant Digital Contact us Feel'Alone Together '. *Alone Together*.
- Twenge, JM, Martin, GN, & Campbell, WK (2018). Decreases in psychological well-being among American adolescents after 2012 and linked to this screen time during the rise of smartphone technology. *Emotion*, 18 (6), 765.
- Twenge, J. M., Joiner, T. E., Rogers, M. L., & Martin, G. N. (2018). Increases in depressive symptoms, suicide-related outcomes, and suicide rates among US adolescents after 2010 and links to increased new media screen time. *Clinical psychological science*, 6(1), 3-17.
- Volkow, ND, Wise, RA, & Baler, R. (2019). The dopamine motive system: implications for drug and food addiction. *Nature Reviews Neuroscience*, 20 (8), 483–494.
- Ward, AF, Duke, K., Gneezy, A., & Bos, MW (2017). Brain drain: The only presence of one's smartphone reduces available cognitive capacity. *Journal of the association for consumer research*, 2 (2), 140-154.
- Woods, HC, & Scott, H. (2016). Sleepy teens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression, and low self-esteem. *Journal of Adolescence*, 51, 41-49.
- Zaccagni, L., Barbieri, D., & Gualdi-Russo, E. (2014). Body composition and physical activity in Italian university students. *Journal of translational medicine*, 12, 1-9.
- Zuboff, S. (2019, January). Surveillance capitalism and the challenge of collective action. In *New Work Forum* (Vol. 28, No. 1, pp 10-29). Sage CA: Los Angeles, CA: Sage Publications.

**How to cite this article:**

Gergov, T., T. Hadzhieva (2025). Influence of Social Networks on the Subjective Feelings of Loneliness in Adolescents and Youth. *International Journal of Digital Research*, E-ISSN: 3033-179X, Vol.1 (3): 35-45. <https://doi.org/10.63711/ijdr.net20250303>

\*\*\*\*\*



# The Impact of ICT on Active Tourism: A Systematic Literature Review of Innovation, Smart Tourism, and Sustainable Development

Anduela Lile<sup>1</sup>, Eglantina Kalluçi<sup>2</sup>, Arben Kaçurri<sup>3</sup>

<sup>1</sup>PhD Candidate, Department of Sport Management and Tourism,

Faculty of Physical Activity and Recreation, Sports University of Tirana, Albania

<sup>2</sup> Professor Doctor, Department of Mathematics, Faculty of Natural Sciences, University of Tirana, Albania

<sup>3</sup> Professor Doctor, Department of Physical Activity and Health, Sports Research Institute,  
Sports University of Tirana, Albania

ORCID ID's: <sup>1</sup> 0009-0004-4109-2543, <sup>2</sup> 0009-0001-9039-1310, <sup>3</sup> 0009-0005-9788-0693

Corresponding author: [alile@ust.edu.al](mailto:alile@ust.edu.al)

<https://doi.org/10.63711/ijdr.net20250305>

## ABSTRACT

This systematic review analysis the impact of Information and Communication Technology (ICT) in active tourism and recreation, its advantages, its disadvantages, and its strategic implication for industry stakeholders. Following the PRISMA guidelines, a systematic research was conducted. Evidences recognize that ICT boosts data-driven management, automation of service delivery and also community participation, improves strategic planning, and boosts crisis resilience. In addition, innovation technologies like gamification, virtual reality, and intelligent infrastructure enrich the tourist experience, particularly for young generations such as Generation Z. However, although the above developments occur, there are challenges that come in terms of digital dependency, unequal access to technology, as well as a potential loss of authenticity in tourist experiences. Overall, ICT is an innovative driver of active tourism, guiding future models of competitiveness, sustainability, and innovation through technology use, marketing, and visitor experience.

**Keywords:** Smart tourism, E-tourism, Innovation, Digital transformation, Sustainable tourism

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

Active tourism, as a dynamic segment of the tourism industry, is undergoing a profound transformation due to the integration of ICT solutions, which are reshaping both the tourist experience and destination management practices. The development of active tourism is increasingly influenced by the strategic use of ICT, enhancing access to information, optimizing and managing destinations,

and improving service quality. The objectives of this systematic literature review were to evaluate the available literature on the effects of ICT on free and active travel, to identify the main advantages and disadvantages, and to provide recommendations for tourism industry stakeholders.

## MATERIALS & METHODS

For this systematic literature review, the standards of reporting article analysis for systematic reviews and meta-analyses were followed (Moher et al., 2009). The main literature search was conducted across three major databases: Web of Science, Scopus, and Google Scholar, which also include studies related to the subject of our research.

The key terms used to search for relevant studies published in the last decade (from 2012 to 2024) were as follows: “Information and Communication Technology (ICT)”; “Systematic Review”, “Recreation” or “Active Tourism”; “Smart Solutions”; “Innovation”; “digital transformation”.

The following criteria were used to select which studies would be included in this literature review: a) Empirical studies and systematic reviews examining how ICT influences active tourism; b) Studies published in English; c) Studies published in peer-reviewed journals. As a result of the search, 38 articles were identified and selected that met the inclusion criteria.

The main themes concerning the impact of ICT on recreation and active tourism are examined and analyzed in this study. This work is based on the phenomenological method as an approach to conducting a qualitative literature review.

The aim of phenomenological research is to arrive at the essence of the lived experience of a phenomenon (Moustakas, 1994), with the goal of reaching the empirical essence of the studies. In applying the phenomenological method as a review technique, the unit of analysis is the research report.

## THEMATIC ANALYSIS

Digital technology and information systems (IS) have transformed tourism and recreation by providing databased services, innovation, and smart tourism ecosystems (Xiang et al., 2021; Malciene & Skauronė, 2019; Buhalis, 2020).

Improved platforms enhance strategic planning, customer engagement, and destination competitiveness (Buhalis & Leung, 2018; Stankov & Filimonau, 2015; Gretzel et al., 2015; Castillo et al., 2021). Electronic communication techniques play an extremely crucial role in tourism, especially during times of crisis.

During the time of COVID-19, electronic resources enabled transparency and trust among stakeholders (Laato et al., 2020) as well as long-term loyalty through constant interaction (Li et al., 2018). Mobile and social media strengthen satisfaction and destination loyalty through offering timely information and personalized experiences (Fan et al., 2019; Liu et al., 2022; Keelson et al., 2024). Destination image and travel decision are also affected by user-generated content (Ghermandi, 2022; Fisher et al., 2018; Cui et al., 2021).

Artificial intelligence and big data shape the future of tourism, making possible personalized services, prediction, and efficient management (Li et al., 2018; Buhalis & Law, 2013). Increasing evidence highlights their role in driving innovation and sustainable growth in the industry (Bulchand-Gidumal et al., 2024).

Studies show that digital technology and online platforms provide powerful tools for promoting tourism and recreational activities, encouraging participation and involving local communities (Sustacha et al., 2023). Moreover, innovative destination management through data-driven approaches can increase efficiency and sustainability in delivering tourist experiences (Miedes-Ugarte et al., 2024).



Research on the impact of social media and digital marketing indicates that these communication channels play a crucial role in shaping tourists' decisions and building emotional connections with destinations (Liu et al., 2023). ICT has transformed the way active tourism is promoted and experienced. Social media distribution increases engagement and strengthens the destination's image, encouraging participation in activities such as hiking, cycling, and water sports (Blanco-Moreno et al., 2024).

At the same time, ICT plays a role in engaging the younger generation (Generation Z) in tourism, a cohort raised with technology that influences attitudes and employment intentions in tourist destinations, particularly UNESCO World Heritage sites (Bermúdez- González et al., 2023). Furthermore, artificial intelligence is enhancing tourism marketing (personalization, automation, impact measurement, etc.), boosting the competitiveness of active tourism offerings (Bulchand-Gidumal et al., 2024).

Mobile applications, booking platforms, and virtual reality tools allow tourists to plan, personalize, and optimize their activities, thereby increasing engagement (Bulchand-Gidumal et al., 2024; Blanco-Moreno et al., 2024). ICT plays a key role in collecting and analyzing data to improve tourism offerings and tailor programs according to the needs of different groups, including younger generations such as Generation Z, who have high expectations for technology and personalized experiences (Bermúdez-González et al., 2023).

The interaction of ICT with transport policies and the promotion of outdoor activities also brings wide-ranging social, environmental, and economic benefits, fostering the sustainability of active tourism (Ding et al., 2024). The use of technology and careful destination design are essential elements for the development of active tourism and its health benefits.

Gamification – the process of modifying systems by integrating game principles in non-game contexts – can increase participant engagement and satisfaction, positively affecting their loyalty to the destination (Kim et al., 2024). Suitable walking and cycling infrastructures, supported by sustainable urban policies, encourage physical activity among both tourists and local communities (Keelson et al., 2024).

Sport and recreational experiences enriched with emotional elements and set in authentic natural environments strengthen positive memories and enhance tourists' connection to the destination (Jeong et al., 2023). Additionally, access to green spaces and sports infrastructure positively influences physical and social well-being, promoting participation in physical activity and recreation within tourism contexts (Ding et al., 2024).

From a technological perspective, the implementation of smart solutions, digital platforms, AI, and gamification strategies has enabled service personalization, operational process optimization, and increased tourist satisfaction, contributing to more efficient and innovative management of tourism offerings (Kim et al., 2024; Bulchand-Gidumal et al., 2024; Blanco-Moreno et al., 2024; Bermúdez-González et al., 2023).

Simultaneously, the role of social media and digital marketing has gained strategic importance, directly influencing tourists' decision-making processes, enhancing interaction with local communities, and building long-term loyalty to destinations (Keelson et al., 2024; Liu et al., 2023; Sustacha et al., 2023).

Beyond the technological and marketing dimensions, the sensory experience of visitors remains a crucial element in active tourism. Factors such as natural landscapes in the context of active sport tourism have been shown to have a positive impact on the creation of lasting memories and the strengthening of a sport-related identity (Jeong, 2023).

Contemporary approaches to destination management, through the integration of smart ICT solutions and sustainability, are shaping new development models aimed at preserving resources and increasing the competitiveness of tourism offerings (Miedes-Ugarte et al., 2024; Ding et al., 2024).

Table 1. Thematic Analysis grouped by main fields and aspects

Main theme	Key Research aspects	References	No. Articles
Information Systems and Technology in Tourism & Recreation	Application and impact of IS and technology in tourism and recreation	<ul style="list-style-type: none"> <li>• Malcienė &amp; Skauronė, 2019;</li> <li>• Xiang et al., 2021;</li> <li>• Buhalis, 2020;</li> <li>• Castillo et al., 2021;</li> <li>• Gretzel et al., 2015;</li> <li>• Buhalis &amp; Leung., 2018;</li> <li>• Stankov &amp; Filimonau, 2015.</li> </ul>	<b>7</b>
Digital Communication Strategies in Tourism Industry	Strategies and impact of digital communication. Information sharing during the COVID-19 pandemic	<ul style="list-style-type: none"> <li>• Laato et al., 2020;</li> <li>• Li et al., 2018.</li> </ul>	<b>2</b>
Mobile Technology and Social Networks	Impact on travel satisfaction and destination loyalty	<ul style="list-style-type: none"> <li>• Fan et al., 2019;</li> <li>• Liu et al., 2022;</li> <li>• Keelson et al., 2024;</li> <li>• Ghermandi, 2022;</li> <li>• Fisher et al., 2018;</li> <li>• Cui et al., 2021.</li> </ul>	<b>6</b>
Artificial Intelligence and Big Data Analytics	Impact and future of AI & Big Data	<ul style="list-style-type: none"> <li>• Li et al., 2018;</li> <li>• Buhalis &amp; Law, 2013;</li> <li>• Bulchand-Gidumal et al., 2024;</li> </ul>	<b>3</b>
Smart Tourism & e-Tourism	Personalization of services, foundations, and developments. Definition, taxonomy, research trends, and critical issues	<ul style="list-style-type: none"> <li>• Buhalis &amp; Amaranggana, 2015;</li> <li>• Buhalis, 2020;</li> <li>• Gretzel et al., 2020;</li> <li>• Adamo, 2018;</li> <li>• Castillo Vizueté et al., 2021;</li> <li>• Robles, 2012;</li> <li>• Wang et al., 2020;</li> <li>• Lee, 2022;</li> <li>• Miedes-Ugarte et al., 2024.</li> </ul>	<b>9</b>
Digital Skills, 21st-Century Skills	Flexible thinking, resilience to change, development of theoretical sampling in practice, and skill provision through	<ul style="list-style-type: none"> <li>• Barak 2018;</li> <li>• Binkley et al., 2012;</li> <li>• Brake, 2014;</li> <li>• Butler et al., 2018;</li> <li>• Franco-Valdez &amp; Valdez-Cervantes, 2020;</li> <li>• Van Laar et al., 2020;</li> <li>• Van Laar et al., 2017.</li> </ul>	<b>7</b>

	experiential learning		
ICT Adoption in Tourism and Recreation Industry and Marketing Activities	ICT adoption model by tourism operators, online marketing activities, and impact on tourists' behavioral intentions	<ul style="list-style-type: none"> <li>• Sustacha et al., 2023;</li> <li>• Kim et al., 2024;</li> <li>• Liu et al., 2023;</li> <li>• Blanco-Moreno et al., 2024.</li> </ul>	<b>4</b>

## CONCLUSION

Evidence shows that ICT significantly enhances data-driven management, automation of service delivery, community participation, and strategic planning, while also strengthening crisis resilience. Moreover, innovative technologies such as gamification, virtual reality, artificial intelligence, and intelligent infrastructure enrich the tourist experience, particularly for younger generations such as Generation Z. These developments highlight the transformative role of ICT in reshaping the way active tourism is designed, promoted, and experienced.

At the same time, the review reveals that several challenges remain. Issues of digital dependency, unequal access to technology, cybersecurity risks, and a potential loss of authenticity in tourist experiences must be addressed if ICT is to serve as a sustainable and equitable driver of tourism development. The findings suggest that technology integration should not only focus on operational efficiency and marketing advantages but also on preserving the human, cultural, and environmental dimensions of active tourism.

Overall, ICT emerges as a key driver of competitiveness, sustainability, and innovation, guiding future tourism models through technology use, marketing strategies, and visitor experience enhancement. The study contributes to the existing literature by systematizing current evidence on ICT's role in active tourism and by highlighting gaps where further empirical research is required – particularly in the areas of long-term sustainability impacts and cross-cultural adoption of smart solutions.

Future research should continue to evaluate the effectiveness of emerging digital tools in fostering inclusive, sustainable, and experience-rich tourism. Particular attention should be given to measuring the ecological and social implications of ICT adoption, as well as the readiness of different destinations and communities to integrate these innovations. By combining digital transformation with sustainable development principles, the tourism industry can ensure that active tourism evolves as both technologically advanced and socially responsible.

### *Declaration by Authors*

**Ethical Approval:** Approved

**Acknowledgement:** Research Thesis of Sports University of Tirana: “ICT impact on Active Tourism and Recreation”

**Source of Funding:** None

**Conflict of Interest:** The authors declare no conflict of interests.



## REFERENCES

- Bermúdez-González, G., Sánchez-Teba, E. M., Benítez-Márquez, M.-D., & Vegas-Melero, J. J. (2023). Generation Z members' intentions to work in tourism in their World Heritage Site hometowns. *Humanities and Social Sciences Communications*, 10(841). <https://doi.org/10.1057/s41599-023-02349-8>
- Blanco-Moreno, S., González-Fernández, A. M., Muñoz-Gallego, P. A., & Casalo, L. V. (2024). Understanding engagement with Instagram posts about tourism destinations. *Journal of Destination Marketing & Management*, 34, 100948. <https://doi.org/10.1016/j.jdmm.2024.100948>
- Buhalis, D. (2020). Technology in tourism – from information communication technologies to eTourism and smart tourism towards ambient intelligence tourism: A perspective article. *Tourism Review*, 75(1), 267–272. <https://doi.org/10.1108/TR-06-2019-0258>
- Buhalis, D., & Law, R. (2013). Progress in information technology and tourism management: 20 years on and 10 years after the Internet – the state of eTourism research. *Tourism Management*, 29(4), 609–623. <https://doi.org/10.1016/j.tourman.2008.01.005>
- Buhalis, D., & Leung, R. (2018). Smart hospitality – Interconnectivity and interoperability towards an ecosystem. *International Journal of Hospitality Management*, 71, 41–50. <https://doi.org/10.1016/j.ijhm.2017.11.011>
- Bulchand-Gidumal, J., Secin, E. W., O'Connor, P., & Buhalis, D. (2024). Artificial intelligence's impact on hospitality and tourism marketing: Exploring key themes and addressing challenges. *Current Issues in Tourism*, 27(14), 2345–2362. <https://doi.org/10.1080/13683500.2023.2229480>
- Castillo Vizuete, D. D., Gavilanes Montoya, A. V., Muñoz Jácome, E. A., Chávez Velásquez, C. R., & Borz, S. A. (2021). An evaluation of the importance of smart tourism tools in the Riobamba Canton, Ecuador. *Sustainability*, 13(16), 9436. <https://doi.org/10.3390/su13169436>
- Cui, N., Malleon, N., Houlden, V., & Comber, A. (2021). Using VGI and social media data to understand urban green space: A narrative literature review. *ISPRS International Journal of Geo-Information*, 10(7), 425. <https://doi.org/10.3390/ijgi10070425>
- Ding, D., Luo, M., Infante, M. F. P., Gunn, L., Salvo, D., Zapata-Diomedí, B., Smith, B., Bellew, W., Bauman, A., Nau, T., & Nguyen, B. (2024). The co-benefits of active travel interventions beyond physical activity: A systematic review. *The Lancet Planetary Health*, 8(10), e790–e803. [https://doi.org/10.1016/S2542-5196\(24\)00201-8](https://doi.org/10.1016/S2542-5196(24)00201-8)
- Fan, D. X., Buhalis, D., & Lin, B. (2019). A tourist typology of online and offline information sources. *Journal of Travel Research*, 58(4), 560–575. <https://doi.org/10.1016/j.annals.2019.102757>
- Fisher, D. M., Wood, S. A., White, E. M., Blahna, D. J., Lange, S., Weinberg, A., & Lia, E. (2018). Recreational use in dispersed public lands measured using social media data and on-site counts. *Journal of Environmental Management*, 222, 465–474. <https://doi.org/10.1016/j.jenvman.2018.05.045>
- Ghermandi, A. (2022). Geolocated social media data counts as a proxy for recreational visits in natural areas: A meta-analysis. *Journal of Environmental Management*, 317, 115325. <https://doi.org/10.1016/j.jenvman.2022.115325>
- Gretzel, U., Sigala, M., Xiang, Z., & Koo, C. (2015). Smart tourism: Foundations and developments. *Electronic Markets*, 25(3), 179–188. <https://doi.org/10.1007/s12525-015-0196-8>
- Jeong, Y. (2023). Exploring tourist behavior in active sports tourism: An analysis of the mediating role of emotions and moderating role of surfing identification. *SAGE Open*, 13(3), 1–15. <https://doi.org/10.1177/21582440231195486>
- Keelson, S. A., Bruce, E., Egala, S. B., Amoah, J., & Jibril, A. B. (2024). Driving forces of social media and its impact on tourists' destination decisions: A uses and gratification theory. *Cogent Social Sciences*, 10(1), 2318878. <https://doi.org/10.1080/23311886.2024.2318878>
- Kim, H., So, K. K. F., Shin, S., & Li, J. (2024). Artificial intelligence in hospitality and tourism: Insights from industry practices, research literature, and expert opinions. *Journal of Hospitality & Tourism Research*. Advance online publication. <https://doi.org/10.1177/10963480241229235>



- Laato, S., Islam, A. N., Islam, M. N., & Whelan, E. (2020). What drives unverified information sharing and cyberchondria during the COVID-19 pandemic? *European Journal of Information Systems*, 29(3), 288–305. <https://doi.org/10.1080/0960085X.2020.1770632>
- Li, J., Xu, L., Tang, L., Wang, S., & Li, L. (2018). Big data in tourism research: A literature review. *Tourism Management*, 68, 301–323. <https://doi.org/10.1016/j.tourman.2018.03.009>
- Liu, H., Zhang, Y., & Wang, J. (2023). Social media marketing, tourist engagement, and destination loyalty in active tourism. *Anatolia*, 34(4), 651–667. <https://doi.org/10.1080/13032917.2023.2282712>
- Liu, J., Wang, C., & Zhang, T. (2022). Delineating the effects of social media marketing activities on Generation Z travel behaviors. *Journal of Travel Research*, 62(5), 1140–1158. <https://doi.org/10.1177/00472875221106394>
- Malcienė, D., & Skauronė, L. (2019). Application of information systems in tourism and leisure sector. *The International Journal of Social Sciences and Humanities Invention*, 6, 5341–5346. <https://doi.org/10.18535/ijsshi/v6i2.11>
- Miedes-Ugarte, B., López-Sánchez, J. A., & Pulido-Fernández, J. I. (2024). Tourism destination governance and smart tourism: Integrating sustainability into management models. *Administrative Sciences*, 15(1), 10. <https://doi.org/10.3390/admsci15010010>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7), e1000097. <https://doi.org/10.1371/journal.pmed.1000097>
- Moustakas, C. (1994). *Phenomenological research methods*. Sage Publications. <https://doi.org/10.4135/9781412995658>
- Stankov, U., Filimonau, V., & Slivar, I. (2019). Calm ICT design in hotels: A critical review of applications and implications. *International Journal of Hospitality Management*, 82, 298–307. <https://doi.org/10.1016/j.ijhm.2018.10.012>
- Sustacha, I., López-Guzmán, T., & Cordente-Rodríguez, M. (2023). Sports tourism and local development: An analysis of active tourism demand. *Journal of Destination Marketing & Management*, 30, 100817. <https://doi.org/10.1016/j.jdmm.2023.100817>
- Xiang, Z., Magnini, V. P., & Fesenmaier, D. R. (2014). Information technology and consumer behavior in travel and tourism: Insights from travel planning using the internet. *Journal of Retailing and Consumer Services*, 22, 244–249.

#### **How to cite this article:**

Lile, A., Kalluçi, E., & Kaçurri, A. (2025). The Impact of ICT on Active Tourism: A Systematic Literature Review of Innovation, Smart Tourism, and Sustainable Development. *International Journal of Digital Research*, 1(3), 46-52. <https://doi.org/10.63711/ijdr.net20250305>

\*\*\*\*\*



# The Role of European Union's Agricultural Policy in the Development of Rural Areas in Bulgaria

Valentin Shlyakov

PhD Student

Department of Geography, Ecology and Environmental Protection  
Faculty of Mathematics and Natural Sciences  
South-West University "Neofit Rilski", Blagoevgrad, Bulgaria  
ORCID ID: 0009-0002-7414-7825, E-mail: [shlyakov@swu.bg](mailto:shlyakov@swu.bg)

<https://doi.org/10.63711/ijdr.net20250306>

## ABSTRACT

This article critically examines the role of the European Union's Common Agricultural Policy (CAP) in shaping the development trajectory of rural areas in Bulgaria. Emphasis is placed on the evolution of CAP measures, their economic, social, and environmental impacts, and their contribution to the structural transformation of Bulgarian agriculture since EU accession. The analysis explores key policy instruments under Pillar I (direct payments) and Pillar II (rural development programmes), with a focus on modernization, competitiveness, sustainability, and demographic resilience. Drawing on strategic policy documents, statistical data, and comparative assessments, the study evaluates the extent to which CAP interventions have supported income stability, stimulated employment, enhanced biodiversity protection, and improved infrastructure in rural regions. Findings indicate that EU support has significantly increased farm productivity, diversified local economies, and strengthened environmental practices, although persistent structural challenges, such as land fragmentation, unequal distribution of subsidies, and demographic decline, continue to limit the full realization of rural development objectives. The article concludes by highlighting policy priorities and strategic directions for the post-2027 programming period, including digital transformation, targeted support for small and medium-sized farms, and stronger integration with cohesion and Green Deal policies.

**Keywords:** *European Union (EU), Agricultural sector, Rural areas, Sustainable development; Competitiveness; Organic farming*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

Rural development constitutes a central pillar of the European Union's Common Agricultural Policy (CAP), functioning as a key instrument for promoting socio-economic cohesion, environmental sustainability, and territorial balance across Member States. For new EU members such as Bulgaria,



CAP support has played a pivotal role in restructuring agricultural production, improving rural infrastructure, and mitigating regional disparities. Approximately 81% of Bulgaria's territory is classified as rural, with nearly 39% of its population residing in these areas, underscoring the strategic significance of agriculture and rural policy for the country's overall development trajectory.

Since Bulgaria's accession to the EU in 2007, CAP interventions have become the principal mechanism for financing rural transformation, encompassing direct payments, investment support, agri-environmental schemes, and community-led local development initiatives. These instruments have contributed to modernization and specialization within the agricultural sector, encouraged the adoption of sustainable farming practices, and supported diversification beyond traditional agricultural activities. Moreover, CAP funding has facilitated infrastructure improvements, enhanced social inclusion, and fostered new employment opportunities, particularly for young farmers and rural entrepreneurs.

Despite these achievements, structural and demographic challenges persist. Land fragmentation, uneven subsidy distribution, limited access to innovation, and continued population decline remain significant barriers to balanced rural growth. Furthermore, the concentration of direct payments among large-scale farms has raised concerns about equity and long-term sustainability. These dynamics highlight the need for a deeper assessment of how CAP policies have shaped rural Bulgaria's socio-economic landscape and how future reforms can address emerging challenges.

The aim of this article is to provide a comprehensive and critical analysis of the role of EU agricultural policy in the development of Bulgaria's rural areas. It evaluates the policy's multidimensional impacts—economic, social, environmental, and demographic—based on strategic documents, official statistical data, and comparative analyses. In doing so, the study seeks to contribute to the academic discourse on rural development policy effectiveness in the context of EU enlargement and to offer evidence-based recommendations for optimizing future interventions beyond 2027.

## LITERATURE REVIEW

The modernization of Bulgarian agriculture and the transformation of rural areas have been strongly influenced by the mechanisms of the Common Agricultural Policy (CAP). EU funding has facilitated the introduction of advanced production technologies, strengthening farm resilience and economic performance (Kirechev, 2023). During the 2007–2013 programming period, direct payments under Pillar I fostered specialization and concentration within Bulgarian agriculture, while in 2014–2020 the sector received almost €7.4 billion in CAP support, of which €5.1 billion were direct payments (Beluhova-Uzunova et al., 2025). These trends underline the structural dependence of Bulgarian agriculture on CAP instruments.

The concept of **endogenous rural development**, which emphasizes mobilizing internal resources rather than relying solely on external subsidies, provides an important theoretical perspective (Patarchanov & Patarchanova, 2014). This approach is closely connected to the principle of partnership, which fosters bottom-up governance and local community participation in rural transformation. However, empirical evidence suggests that the implementation of this principle in Bulgaria has been uneven, with varying degrees of local engagement and success.

Recent studies further highlight the dual role of CAP payments. On the one hand, they have improved competitiveness, encouraged farm modernization, and supported sustainable practices (Beluhova-Uzunova et al., 2021). On the other, they have exacerbated structural imbalances, as subsidies remain concentrated among larger holdings, while the number of farms declined by 64% between 2010 and 2020 (Beluhova-Uzunova et al., 2024). This reflects a broader debate in CAP literature regarding



the **fairness and distributive outcomes** of agricultural policy, particularly in countries with fragmented land ownership such as Bulgaria (Ivanova, 2023).

The environmental dimension of CAP has also been widely studied. Ivanov (2022) emphasizes the positive contribution of agro-ecological measures to biodiversity preservation and soil fertility, while Stoeva, Dirimanova, and Georgiev (2023) stress the importance of extension and advisory services for promoting environmentally sustainable practices. Nonetheless, the balance between production-oriented objectives and ecological sustainability remains a challenge, as seen in the tensions between large-scale intensive farming and the preservation of high nature value areas.

Another strand of literature focuses on the **social and demographic impacts** of CAP. Patarchanov (2019) argues that rural development requires not only agricultural modernization but also diversification of employment opportunities in industry and services. Without complementary infrastructure investments, depopulation and unfavorable demographic trends are likely to persist. This perspective is supported by studies indicating that inadequate transport and service infrastructure, particularly in peripheral and mountainous regions, exacerbates outmigration and mortality rates (Patarchanov, 2019; Ivanova, 2023).

Finally, the governance dimension is central to understanding policy effectiveness. The success of CAP implementation in Bulgaria is strongly shaped by institutional capacity and coordination between national authorities and EU institutions (Georgiev, Stoeva & Dirimanova, 2023). Weaknesses in administrative efficiency, transparency, and monitoring mechanisms limit the full potential of CAP-funded measures, highlighting the need for improved governance structures.

Overall, the literature suggests that while CAP has been indispensable for Bulgaria's rural development, its outcomes are mixed. Achievements in modernization, competitiveness, and environmental protection coexist with structural inequalities, demographic decline, and governance challenges. This creates a clear gap for further academic inquiry into how CAP interventions can be better targeted, integrated, and adapted to Bulgaria's specific rural realities

## MATERIALS & METHODS

Key policy and strategic documents were analyzed to extract data on national priorities, financial allocations, and specific interventions in the agricultural sector and rural development. The following sources were utilized: Strategic Plan for the Development of Agriculture and Rural Areas of the Republic of Bulgaria for the period 2023–2027 (CAP Strategic Plan) – the core national implementation document for the CAP, containing objectives, SWOT analyses, identified needs, intervention strategies, and funding allocations;

National Reform Programme 2024 (NRP 2024) – Which outlines Bulgaria's broader economic and structural reform agenda, including EU funds management and sustainability goals;

Strategy for the Development of Human Resources in the Social Sphere 2024–2030 – analyzed to understand the social dimension and human capital aspects linked to rural services and social inclusion measures in agricultural regions.

Thematic content analysis was conducted on these documents to identify and categorize CAP priorities related to income support, rural employment, environmental sustainability, and generational renewal.



## Statistical Data Review

Quantitative data on funding volumes, beneficiary structures, and rural demographic dynamics were gathered from: The National Statistical Institute (NSI); Publicly available EC CAP monitoring dashboards; National databases on rural development project implementation. The data was used to trace trends in CAP funding absorption, sectoral impact (especially for young farmers and ecological practices), and regional disparities.

## Comparative Regional Analysis

The study includes a regional case assessment of selected rural municipalities in Bulgaria's Southwest Planning Region (Yugozapaden raion za planirane), with a focus on the Blagoevgrad district. This area was chosen due to its socio-economic diversity and active participation in CAP-funded measures under both Pillar I and II.

Local development strategies (CLLD), LEADER initiatives, and rural business support under EAFRD were qualitatively assessed based on secondary reports and regional profiles.

## Methodological Limitations

The research relies primarily on secondary data and official documents, which may be subject to institutional reporting bias or limited transparency on micro-level implementation. Future studies could integrate field surveys or interviews with stakeholders (farmers, local administrations, and NGOs) for deeper insight.

EU-funded investment support has played a key role in enabling Bulgarian farms to modernize their production technologies and strengthen their economic resilience (Kirechev, 2023). Beluhova Uzunova et al. (2025) emphasize that during 2007–2013, CAP direct payments fostered substantial specialization and concentration within Bulgarian agriculture. In the following programming period (2014–2020), almost €7.4 billion was allocated to the sector and rural areas through the CAP, of which €5.1 billion consisted of direct payments. Data has been visualized through line and bar charts comparing EU funding levels to employment, young farmer support, and rural poverty reduction.

## Strategic and Financial Framework of CAP in Bulgaria

The Rural Development Programme (RDP) 2014–2020. Total budget: EUR 3.8 billion (EUR 3.1 billion EU, EUR 0.7 billion national). Focus: competitiveness, environmental protection, rural vitality. 3705 young farmers supported, 4000+ small-scale farmers modernized. 113,000 hectares under agroecology and Natura 2000 support.

Endogenous development emphasizes strengthening local capacities and mobilizing internal resources instead of depending exclusively on external subsidies (Patarchanov & Patarchanova, 2014).

## Strategic Plan 2023–2027

Priorities: sustainable income, environmental protection, digital innovation. Includes results-based eco-schemes, generational renewal, and support for marginalised regions. New measures: carbon farming pilots, broadband rural access, circular economy projects.

### Pillar I – Direct Payments

Direct support per hectare (SAPs), eco-schemes, and coupled support for livestock and protein crops €1.7 billion allocated for 2023–2027 under Pillar I

According to Beluhova-Uzunova et al. (2025), the First Pillar of the CAP predominantly favors large-scale farms, thereby deepening inequalities in Bulgarian agriculture, while small and medium-sized farms obtain only a marginal share of direct payments.

Earlier research by the same author (Beluhova-Uzunova et al., 2019) highlights that although



small farms—representing over 86% of all holdings in Bulgaria—play an important role in rural employment and biodiversity preservation, their share of utilized agricultural land and standard output declined between 2010 and 2016.

### National Co-Financing and Complementary Measures

Co-financing of irrigation modernization: 80 projects under M4.3. €225 million allocated for innovation and smart farming.

Complementary state aid for volatile markets and short-term credits (2022–2024). Strategic Priorities by Specific Objectives (SO1–SO9) According to the CAP Strategic Plan for 2023–2027 (SP за P3CP 2023–2027), Bulgaria aligns its rural development vision with nine EU-defined specific objectives:

- SO1: Viable farm income and sector resilience – Focus on direct income support and competitiveness
- SO2: Enhance market orientation and competitiveness – Investment in physical assets, modernization
- SO3: Strengthen position in the value chain – Support for producer organizations and short supply chains
- SO4: Climate change mitigation – Carbon farming, biodiversity incentives, and energy efficiency
- SO5: Sustainable resource use – Organic farming, precision irrigation, and agroforestry
- SO6: Protect biodiversity, enhance ecosystems – Natura 2000 and High Nature Value farming support
- SO7: Attract and retain young farmers – Grant schemes, generational renewal training
- SO8: Promote employment and local development – LEADER/CLLD projects, rural SMEs
- SO9: Ensure food safety and animal welfare – Veterinary services, traceability, and quality schemes

Table 1: CAP 2023–2027 Interventions by Specific Objective. Source: Strategic Plan for Agriculture and Rural Development 2023–2027.

Specific Objective	Core Interventions	Indicative Budget (EUR million)
SO1	Direct payments, coupled support	950
SO2	Investments M4.1, M6.1	650
SO3	Producer groups, short chains	140
SO4	Eco-schemes, agri-environment	510
SO5	Organic support, water projects	280
SO6	Natura 2000, AES	210
SO7	Start-up aid for young farmers	160
SO8	LEADER, diversification, training	310

SO9	Quality schemes, vet measures	120
-----	-------------------------------	-----

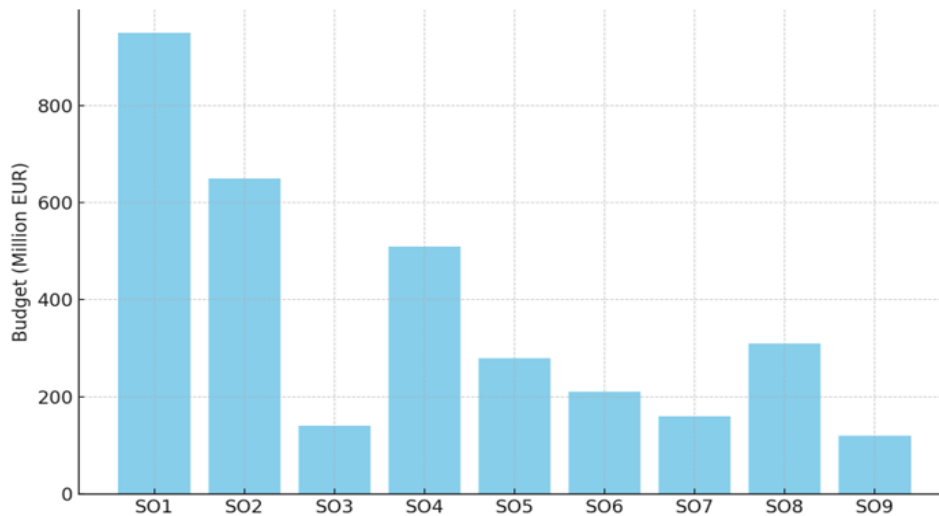


Figure 1: Budget Allocation by CAP Objectives (SO1–SO9). Source: Strategic Plan for Agriculture and Rural Development 2023–2027.

**Cross-Cutting Objective (XCO): Knowledge and Innovation** The CAP Plan also outlines a cross-cutting objective (XCO) on fostering innovation, digital transition, and knowledge exchange. The strategy includes: Establishing regional advisory centres and digital platforms. €95 million for farm innovation projects under EIP-AGRI. Partnerships with academic institutions for agri-research

In spatial development, the partnership principle plays a pivotal role by encouraging bottom-up strategies and actively engaging local communities in the process (Patarchanov & Patarchanova, 2014).

**Consistency with the EU Green Deal and Farm to Fork** Strategic coherence is ensured through:

Reduction of greenhouse gas emissions in livestock by 12% by 2027. 25% of utilised agricultural area (UAA) under organic farming by 2030

Climate-resilient varieties and carbon sequestration pilots (e.g., GAEC standards and eco-schemes). **Monitoring Framework and Result Indicators** The CAP Plan includes 44 result indicators to track: Farm income variation

Employment levels in rural areas. Adoption of environmental practices (e.g., AES uptake, organic ha). Youth participation in farming. **Linkages to National Plans and Recovery Instruments** CAP strategic design integrates objectives from:

National Recovery and Resilience Plan (NRRP): irrigation, digitization, energy transition

National Programme for Reforms (NPR): modernization, access to finance, rural entrepreneurship. **Strategy for Human Resources in the Social Sector 2024–2030:** improving rural service delivery, care for vulnerable populations.

**Institutional Framework and Implementation Bodies.** Managing Authority: Ministry of Agriculture and Food. Paying Agency: State Fund Agriculture (SFA). Monitoring Committee: Composed of government, NGO, and EU observers.

These strategic, institutional, and thematic integrations illustrate a highly structured approach to CAP implementation in Bulgaria, reinforcing rural development as a multidimensional process blending economic growth, social resilience, and environmental protection.

The following sections examine the real-world outcomes of these policies, linking funding to measurable changes in Bulgaria's rural landscape.

### Measurable Impacts and Outcomes of CAP Implementation in Bulgaria

**Agricultural Production and Farm Competitiveness** Thanks to CAP investment under SO1 and SO2, farm income in Bulgaria has improved steadily. According to the Agrarian Report 2024:

Gross agricultural output grew by 6.2% between 2020 and 2023. Average net farm income per agricultural holding increased by 13.8%. 68% of supported farms adopted new technologies, including precision agriculture

Direct payments under the Common Agricultural Policy have played a central role in restructuring Bulgarian agriculture, fostering competitiveness and encouraging sustainable rural development (Beluhova-Uzunova et al., 2021).

Youth and Employment in Rural Areas SO7 and SO8 interventions led to: 3,705 young farmers supported under Measure 6.1. 600+ LEADER local action groups funded. Employment in rural regions increased by 4.5% (2015–2023) *Extension and advisory services play an important role in enhancing farmers' knowledge and promoting environmentally sustainable farming practices in Bulgaria.* (Stoeva, Dirimanova & Georgiev, 2023).

Table 2: Rural Employment Trends and CAP Support. Source: Bulgarian National Statistical Institute and CAP Monitoring Reports.

Year	Rural Employment (%)	Young Farmer Beneficiaries	LEADER Jobs Created
2015	39.5	1000	200
2017	40.2	1800	320
2019	41.0	2800	430
2021	41.8	3500	550
2023	42.3	3705	600

**Environmental Sustainability and Climate Impact Support** for SO4, SO5, and SO6 enabled:

Over 52,000 hectares under organic certification. 113,000 hectares managed under agri-environmental schemes. 1,400 farmers engaged in carbon sequestration pilot projects

Recent evidence indicates that, despite the CAP's post-2023 focus on reducing disparities, the number of farms in Bulgaria declined by 64% between 2010 and 2020, while direct payments remained concentrated among large holdings, casting doubt on the fairness of rural development (Beluhova-Uzunova et al., 2024).

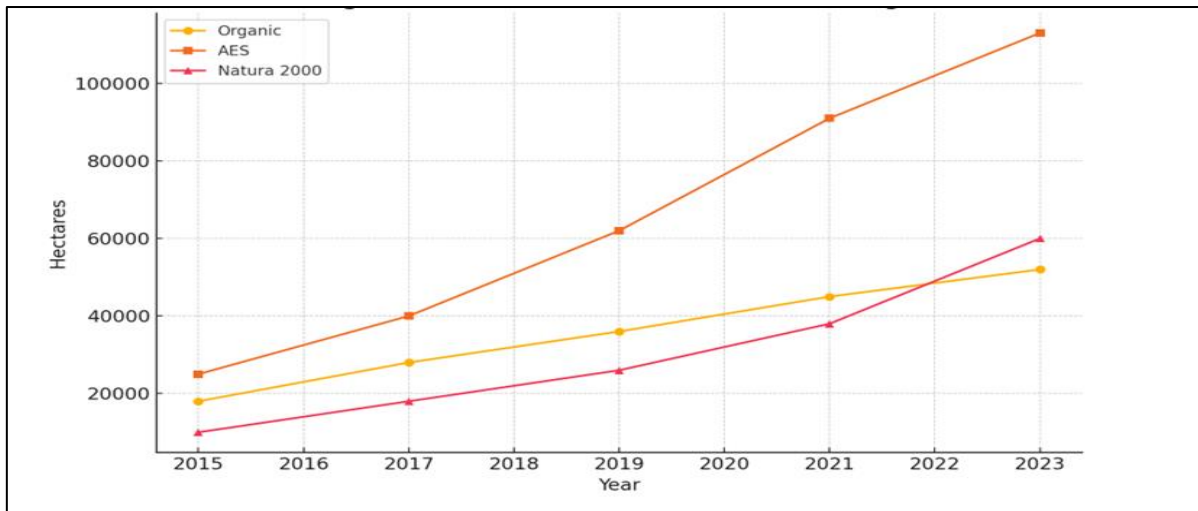


Figure 2: Area (ha) Covered by CAP Environmental Interventions (2015–2023) (Line chart comparing organic, AES, and Natura 2000 land areas over time. *Source: EC CAP Indicators Dashboard.*)

Social Inclusion and Infrastructure Modernization SO8 and NRRP-linked CAP investments delivered: Renovation of 280 schools, 94 community centres, and 1,500 km of rural roads

Improved healthcare outreach in 30 municipalities via mobile rural units. Gender-balanced participation: 45% of LEADER project leads were women. Policy Coherence and Integrated Rural Transformation CAP measures were aligned with national strategies (NPR 2024, NRRP) and enhanced by: Cross-financing of irrigation infrastructure (M4.3, NRRP, Green Deal). Rural digitalization through CAP XCO and NRRP digital hubs. Training programs funded under the Social Strategy 2024–2030 and CAP

## DISCUSSION

**Strengths:** Significant rise in farm modernization and productivity. High alignment between CAP and national reform priorities. Growth in employment, youth inclusion, and digitalization

**Weaknesses:** Bureaucratic procedures hinder timely access to funds. Fragmented land structure limits economies of scale. Uneven CAP benefits across regions (e.g., Northwest Bulgaria underfunded)

**Opportunities:** Scaling carbon farming through eco-schemes. Further integration with EU Green Deal financing. Rural tourism and ecosystem services as diversification paths.

In the absence of effective government policy, economic integration may result in deindustrialization of peripheral regions, which is why infrastructure development should primarily focus on internal needs (Patarchanov & Patarchanova, 2014).

**Threats:** Climate extremes impacting yields. Aging farming population despite SO7 efforts. Risk of overlapping measures under multiple instruments (CAP, NRRP, cohesion funds) The positive outcomes of CAP funding are evident in infrastructure, employment, and ecological results.

However, challenges remain: Complexity in administrative procedures and digital platforms. Structural fragmentation and aging farmer population. Unequal regional access to innovation and credit

Table 2: Rural Employment Trends and CAP Support. Source: Bulgarian National Statistical Institute and CAP Monitoring Reports.

Year	EU CAP Funding (Billion EUR)	Rural Employment Rate (%)	Number of Young Farmers Supported	Biofarming Area (ha)
2015	2.9	39.5	1000	18,000
2017	3.2	40.2	1800	28,000
2019	3.4	41.0	2800	36,000
2021	3.6	41.8	3500	45,000
2023	3.8	42.3	3705	52,000

Rural development policies in Bulgaria face significant obstacles, as land fragmentation and ownership disputes continue to hinder improvements in agricultural productivity (Ivanova, 2023). Greater coherence is needed with the EU Biodiversity Strategy and Farm to Fork Strategy.

Also, regionalized monitoring and participatory planning must be enhanced. Bioenergy as diversification: Biomass offers potential for income and employment, but only under strict criteria – using residues and avoiding competition with food production. Adaptive policies via IA: Regular impact assessments at measure and regional level, with transparent indicators, improve policy effectiveness and accountability.

Table 3: CAP Funding vs Rural Employment Rate (2015–2023). Source: Bulgarian National Statistical Institute and Ministry of Finance Reports.

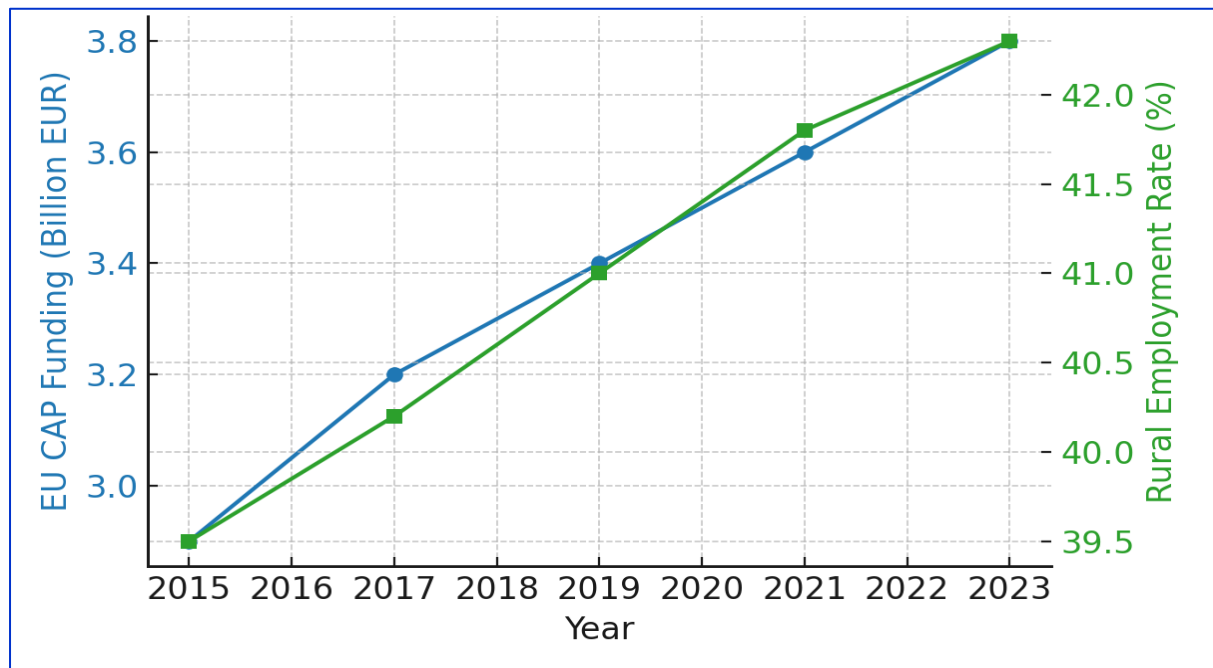


Figure 3: CAP Funding vs Rural Employment Rate (2015–2023). Sources: Ministry of Agriculture and National Statistical Institute of Bulgaria..

Table 4: Key Measures and Achievements from CAP Implementation. Source: Agrarian Report 2024.

Measure	Objective	Achieved Output (2020–2023)
M6.1	Support for Young Farmers	3705 beneficiaries
M4.1	Investment in Physical Assets	6000+ farm projects
M7.2	Infrastructure in Rural Areas	1500 km roads, 280 schools renovated
M10	Agroecological practices	113,000 ha environmentally managed land

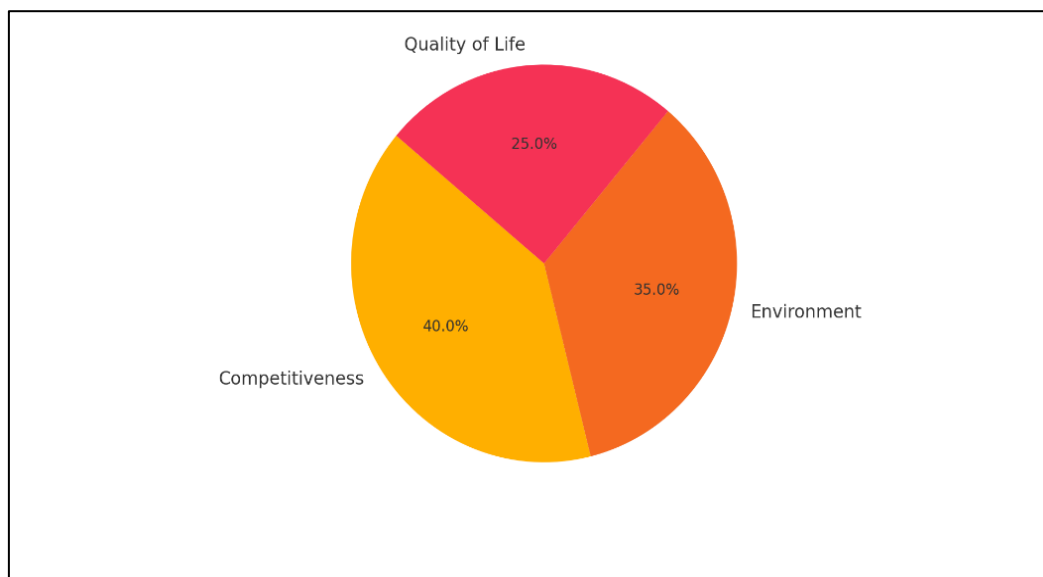


Figure 4: Distribution of CAP Pillar II Investments by Axis (2020–2023) (A pie chart illustrating % distribution for competitiveness, environment, and quality of life. Source: CAP Monitoring Dashboard, 2024. Agro-ecological schemes introduced through the CAP have played an important role in maintaining biodiversity and enhancing soil fertility in Bulgaria’s rural areas (Ivanov, 2022).

### Impact on Rural Areas

CAP funding has significantly improved infrastructure and basic services in Bulgaria’s rural regions. Broadband access has expanded to more than 2,200 villages, reducing the digital divide and enabling new economic opportunities. Water supply systems have been modernized in 43 municipalities, contributing to improved living standards and public health.

These developments have increased the attractiveness of rural areas for both residents and investors, helping to mitigate some aspects of depopulation.

### Economic Diversification and Job Creation

Support under measures such as M6.4 and LEADER strategies has encouraged diversification of rural economies beyond agriculture. As a result, over 3,500 jobs have been created in small and medium-sized enterprises, and approximately 600 positions have been generated through community-led local development projects. Such diversification reduces dependency on primary agricultural activities and enhances regional economic resilience.

### Demographic and Social Effects

CAP interventions have also influenced demographic dynamics. Youth retention in rural areas improved by 6.2% according to NSI (2023), while the rural poverty rate declined by 4.3 percentage points between 2015 and 2022. However, insufficient transport infrastructure — particularly the lack of adequate rail networks — continues to restrict access to essential services and remains a barrier to reversing depopulation trends (Patarchanov, 2019).

### Environmental and Climate Results

Environmental outcomes demonstrate CAP's contribution to sustainability. Over 60,000 hectares of land within Natura 2000 zones have received compensatory payments, and 1,400 farmers are participating in carbon sequestration pilot schemes. These measures contribute to climate change mitigation, biodiversity conservation, and improved soil management practices.

## The Role of CAP in Addressing Demographic Decline and Territorial Disparities

### Population Loss in Rural Regions

Bulgaria's rural municipalities experienced a population decline of approximately 13% between 2007 and 2023 (NSI). CAP measures aim to counteract this through grants for young farmers (SO7), community-led local development (LEADER/CLLD) strategies targeting depopulated municipalities, and investments in social infrastructure such as healthcare, education, and digital connectivity.

### Regional Development Disparities

Significant regional imbalances persist, with northwestern regions such as Vidin, Montana, and Vratsa historically receiving less investment. In response, the CAP Strategic Plan 2023–2027 mandates that at least 15% of rural development funding be allocated to “lagging regions.” Additionally, projects from NUTS-3 regions with GDP per capita below 50% of the national average receive priority scoring, promoting more equitable territorial development.

Table 5: Territorial Allocation Measures for Disadvantaged Regions (2023–2027). Source: Strategic Plan for Agriculture and Rural Development 2023–2027.

Region	Designation	CAP Measures Applied	Budget Share (%)
Northwest BG	Most disadvantaged	M4.1, M6.1, M7.2, M19 (LEADER)	17
South-Central	Moderately lagging	M4.1, M10, M11, XCO (digital innovation)	13
Southeast BG	Border rural region	M6.4, M7.4, M16 (cooperation projects)	12



## Cross-Sectoral Synergies with EU and National Instruments

The CAP works in close alignment with the NRRP to amplify the effects of rural development investments. For instance, €200 million in water infrastructure funding complements CAP-supported irrigation projects, while €90 million allocated to agri-digital transformation enhances precision farming and e-voucher systems.

Joint initiatives with the national social strategy aim to improve care access for elderly and vulnerable populations in rural regions. CAP Measure M7.4 co-finances integrated rural service hubs, and early-childhood service centers have been introduced in depopulating villages. These efforts support inclusive rural development and social cohesion.

CAP eco-schemes and conditionality standards are aligned with Green Deal objectives, including reductions in pesticide use, improvements in soil carbon sequestration, and biodiversity protection. Collaborative projects under the LIFE programme further support peatland preservation and grassland restoration, enhancing the environmental impact of CAP measures.

## Future Outlook: CAP Beyond 2027

As the EU prepares for the next programming period (post-2027), Bulgaria's priorities should include: Expanding digital tools and AI in rural advisory systems. Enhancing landscape-scale climate adaptation schemes. Integrating rural development into broader territorial cohesion policy. Introducing multi-annual social contracts for rural depopulation reversal.

Looking ahead, the post-2027 programming period will require a stronger emphasis on innovation, climate adaptation, and demographic resilience. Key priorities should include expanding digital tools and artificial intelligence in rural advisory services, implementing large-scale climate adaptation schemes, and integrating rural policy more closely into the EU's territorial cohesion framework. Additionally, multi-annual social contracts could be introduced to directly address population decline and improve service provision in depopulated areas.

## Conclusion

The CAP has clearly transformed rural Bulgaria in multiple dimensions – economic, environmental, and social. Yet the road ahead requires refinement of targeting and administrative efficiency. A “place-based” approach, recognizing the diversity of rural areas and their needs, is vital.

Key messages: Maintain strong CAP budget allocations, especially for Pillar II

Invest in social infrastructure and care economy in rural areas. Enhance synergies with cohesion and digital policies. Prioritize data-driven decision-making and participatory planning.

## Insights from the National Reform Programme” and “Comparative Analysis

The NRP 2024, prepared by the Ministry of Finance, outlines strategic commitments aligning national priorities with CAP funding and instruments. Key agricultural and rural development insights include: Alignment with Council Recommendations (2023): CAP targets directly address the socio-economic disparity, employment, and green transition noted in EU recommendations. Public Investment Forecast (2024–2027): Over €1.5 billion in rural infrastructure, 40% of which overlaps with CAP funding (e.g., irrigation, roads, digital hubs).

Rural Human Capital: Vocational training for 12,000 rural residents is planned under ESF+, harmonized with CAP measures M1 (training) and M2 (advisory services). Sustainable Development Goals (SDGs): CAP directly contributes to Bulgaria's progress on SDG 2 (Zero Hunger), SDG 8 (Decent Work), and SDG 13 (Climate Action).



## Social Dimensions and Human Resource Strategy (2024–2030)

The "Strategy for the Development of Human Resources in the Social Sphere 2024–2030" addresses gaps in rural human capital, labor motivation, and care infrastructure. CAP supports these goals via:

Measure M7.4: Co-investments in rural social services (care centers, childcare)

Cross-Sectoral Training Programs: Joint funding with M1 and the National Employment Agency

Career Development Pathways: CAP helps align farm diversification (M6.4) with employment in social and care-based entrepreneurship

**Projection (2026–2030) Three scenarios for the evolution of Bulgarian rural areas were developed, based on the proposed index:**

1. Baseline (“inertia”): modest improvement of economic indicators; slow income convergence; IYPCP rises by +5–8 points.
2. Green Diversification (preferred): targeted support for small/medium farms, eco-investments, controlled bioenergy from residues; IYPCP rises by +12–18 points, especially in governance and social pillars.
3. Stagnation (risk): weak IA and policy targeting; persistent disparities; IYPCP stagnates or declines in social dimensions.

## Comparative Analysis: Bulgaria and Selected EU Countries

The objective of this comparative analysis is to contextualize the impact of the Common Agricultural Policy (CAP) on rural development in Bulgaria by means of a direct comparison with several representative EU Member States. This comparison aims to: assess the extent to which the trends observed in Bulgaria are country-specific or reflect broader regional patterns, identify policies and instruments that demonstrate greater effectiveness, and validate the proposed indicators within the National Rural Development Programme (NRDP).

### Selection of Countries for Comparison

For conducting a meaningful and productive comparative analysis, the following countries have been selected: Romania — shares a similar agricultural structure and transitional experience; suitable for regional/Balkan comparison. Hungary and Poland — Central European countries with more advanced agricultural modernization and significant access to investment support. Greece — a Southern European country with a high proportion of small farms and specific rural challenges. Spain — an example of pronounced regional disparities, with a strong role of environmental measures and bioenergy in certain regions. Comparative benchmark: EU average / EU-27 (for standardized reference).

### Period of Comparison

The analysis focuses on two key periods: a retrospective view of 2007–2015 (capturing the early post-accession effects) and the 2014–2020 period (the current programming cycle), with a brief projection or indicative assessment towards 2030 based on scenario analysis.

### Comparative Overview (Key Observations)

The comparative analysis of agricultural productivity and rural development highlights several important trends across the selected EU Member States. In Bulgaria, agriculture remains an economically significant sector, contributing approximately 3–4% of national GVA in certain years; however, GVA per worker and rural household incomes have grown more slowly than the EU average, reflecting a persistent lag in rural income development (European Commission, Agriculture and Rural Development).



Poland and Hungary exhibit higher GVA per worker and more intensive agricultural modernization, resulting in stronger economic outcomes within the sector. Romania displays structural characteristics and challenges similar to those of Bulgaria, including a high share of small and family farms and GVA per worker that generally remains below the EU average, albeit with notable regional variations. Spain demonstrates pronounced regional disparities, with some regions achieving high productivity supported by environmental and investment programs, while eastern and mountainous areas experience demographic decline and weaker economic performance.

### **Agricultural Productivity (GVA per Worker)**

**Bulgaria:** Agriculture remains an economically significant sector, contributing around 3–4% of national GVA in certain years. However, GVA per worker and rural household incomes have grown more slowly than the EU average, reflecting a lag in rural income development (European Commission, Agriculture and Rural Development).

**Poland and Hungary:** These countries exhibit higher average GVA per worker and more intensive agricultural modernization, resulting in relatively stronger economic outcomes in the agricultural sector (European Commission, Agriculture and Rural Development).

**Romania:** Similar structural challenges to Bulgaria exist, including a high share of small and family farms. GVA per worker often remains below the EU average, although significant regional disparities are observed (European Commission, Agriculture and Rural Development).

**Spain:** Strong regional differences are evident. Some regions demonstrate high productivity and successful eco-investment programs, while eastern and mountainous areas experience demographic decline and weaker economic performance (Financial Times).

**Interpretation:** Bulgaria lags behind the “modernized” new Member States (Poland, Hungary) in terms of agricultural productivity and rural incomes, partially resembling Romania regarding structural challenges.

### **Access to Investment Support and Inequality**

Data from FADN and analytical assessments indicate a strong concentration of investment support in larger, more professional farms across most countries, including Bulgaria. Small farms often fail to access measures, resulting in asymmetrical impacts: modernization benefits larger farms, while smaller farms are disadvantaged (capreform.eu; European Court of Auditors).

In Poland and Hungary, complementary programs for farm cooperatives and young farmers partially improved access for small and new entrants. In Bulgaria, such effects were less pronounced during the observed period (European Commission, Agriculture and Rural Development).

**Interpretation:** The model of support concentrated in large farms is common in Central and Eastern Europe. Countries with additional cooperative or young farmer schemes achieve a more equitable distribution of benefits.

### **Social Risks: Poverty and Rural Employment**

**Bulgaria:** Rural areas face a high risk of poverty and social exclusion, estimated at 35–40%, significantly higher than urban areas. This pattern is typical for Balkan and Eastern European countries (European Commission). **Romania:** Similarly high levels of rural poverty are observed, occasionally exceeding those in Bulgaria.

Poland, Hungary, Spain: Despite regional variations, average rural poverty risk is generally lower than in Bulgaria and Romania, reflecting stronger economic performance and more effective structural transformation (European Commission, Agriculture and Rural Development).

Interpretation: Social vulnerability remains a key challenge for Bulgaria, suggesting that CAP and NRDP measures should strongly target employment, services, and income support.

### **Demographic Pressure and Long-Term Vulnerability**

Eastern European countries, including Bulgaria and Romania, experience pronounced demographic erosion in rural areas: population outflows, aging, and challenges in maintaining services. This limits the capacity to leverage investment effectively. Recent analyses indicate significant rural population losses in EU countries between 2014 and 2024 (Financial Times; European Commission).

### **Bioenergy and Environmental Diversification**

Spain, and certain regions in Poland and Hungary, have more advanced agricultural bioenergy and eco-investment projects. In Bulgaria, the potential exists (biomass, residues), but implementation requires careful planning to avoid competition with food production. Scientific reviews caution against unsustainable deployment of bio-crops (ScienceDirect; European Commission, Agriculture and Rural Development). Interpretation: Bulgaria can utilize bioenergy for diversification, provided it is based on residues and adheres to targeted environmental requirements.

### **Consolidated Key Findings**

Bulgaria shares many structural weaknesses with Romania, including a high share of small farms, elevated poverty levels, demographic decline, and slower GVA growth. Meanwhile, Poland and Hungary demonstrate stronger modernization and more balanced support distribution due to cooperative models and young farmer initiatives. Across the EU, CAP support tends to consolidate productivity but risks increasing inequality if compensatory policies are absent.

To address these disparities, Bulgaria should prioritize targeted funding for small and young farmers, streamline administrative requirements, and integrate social services into rural development strategies. Annual monitoring and transparent impact assessments would further improve policy adaptability and ensure that support reaches its intended beneficiaries. Promoting cooperatives, local processing, and sustainable bioenergy initiatives can enhance value creation and resilience in rural economies..

### **Practical Recommendations (Comparative-Informed)**

Based on good practices and comparative observations: Targeted Funding for Small and Young Farmers: Apply bonuses and networked funding mechanisms while minimizing administrative barriers (Polish and Hungarian best practices). Combine Investments with Social Infrastructure: Include services, childcare, and digital connectivity to address demographic decline (European analyses on rural revitalization; Financial Times). Annual Monitoring and Publication of IA/Indicators: Track who benefits from support and adjust programs accordingly—a critical tool for adaptive policy (European Commission). Support for Cooperatives and Local Processing: Reduces dependence on large farms and increases local added value (capreform.eu). Sustainable Bioenergy Development: Use only residues/waste and avoid competition with arable land; combine with biodiversity protection measures.

### **Fiscal Coordination and National Budget Contributions**

Effective implementation of the Common Agricultural Policy (CAP) in Bulgaria relies on a robust financial framework that integrates both EU and national budgetary contributions. According to the



Fiscal Strategy 2025, the country's co-financing structure for CAP interventions amounts to approximately €2.45 billion from EU funds and €740 million from the national budget for the 2023–2027 programming period. This partnership underlines the government's commitment to aligning domestic fiscal policy with EU agricultural priorities.

A significant share of this funding is directed toward infrastructure development and technological innovation. For example, irrigation modernization projects are financed through a combination of 65% CAP funds and 35% national and NRRP contributions, ensuring the modernization of water management systems crucial for climate resilience and productivity. Similarly, €65 million from national innovation funds complements CAP's cross-cutting objectives (XCO) by supporting the digital transformation of agriculture and the introduction of precision farming technologies.

Public procurement reforms have also been introduced to improve the efficiency and transparency of CAP-related tenders. Monitoring through the Agency for Public Procurement (AOP) aims to prevent delays and irregularities, enhancing the effectiveness of rural development projects and safeguarding EU financial interests.

### Administrative and Regulatory Frameworks

The governance of CAP implementation in Bulgaria is supported by a comprehensive regulatory framework designed to ensure transparency, compliance, and effective use of resources. Key elements of this framework include:

- **AFKOS (Anti-Fraud Coordination Service):** Coordinates national efforts to protect EU financial interests and prevent misuse of CAP funds.
- **GIS-Based Monitoring Systems:** Utilize satellite technology for real-time monitoring of agri-environmental measures, ensuring compliance and improving data accuracy.
- **Public Procurement Compliance (ZOP):** Ensures that rural development projects adhere to national procurement legislation and EU standards.
- **E-Voucher Portals:** Reduce digital exclusion by providing smallholders with simplified access to support schemes, particularly in training and advisory services under Measures M1 and M2.

These regulatory mechanisms collectively enhance the credibility of CAP implementation, improve administrative efficiency, and ensure that financial resources are used effectively to achieve rural development objectives.

### Governance and Stakeholder Involvement

Strong governance structures and inclusive stakeholder engagement are essential for the successful implementation of CAP measures. The *Monitoring Committee for CAP 2023–2027* includes a broad range of stakeholders, such as:

- **Public institutions:** Ministry of Agriculture and Food, Ministry of Finance, Ministry of Regional Development and Public Works, and Ministry of Labour and Social Policy.
- **Civil society and NGOs:** Environmental groups, women's organizations, and farmer associations.
- **Academic institutions:** Research institutes and universities providing policy expertise and data analysis.
- **Private sector representatives:** Agribusiness chambers and cooperative associations.



This participatory governance model strengthens policy legitimacy, improves project relevance, and facilitates regionally tailored implementation strategies. It also enhances feedback mechanisms, allowing for the continuous refinement of CAP measures based on stakeholder input and real-world outcomes.

## CONCLUSION

The Common Agricultural Policy has been a fundamental driver of rural transformation in Bulgaria, contributing significantly to economic modernization, environmental sustainability, and social cohesion. Direct payments, rural development programs, and agri-environmental schemes have improved farm productivity, diversified rural economies, and enhanced infrastructure and service provision. These achievements have supported broader national priorities, including employment generation, social inclusion, and progress toward the Sustainable Development Goals.

Nevertheless, several structural challenges persist. Land fragmentation, uneven distribution of subsidies, demographic decline, and unequal regional development continue to limit the full potential of CAP interventions. Administrative complexity and disparities in access to innovation and financial resources further constrain small and medium-sized farms, which are essential for sustainable rural development.

To address these challenges and maximize CAP's future impact, several strategic recommendations emerge from this analysis:

1. Simplify administrative procedures and expand digitalization of CAP portals to reduce barriers for beneficiaries and improve fund absorption.
2. Target support to vulnerable regions and farm types, particularly in Northwest Bulgaria and remote mountainous areas, through tailored measures and enhanced co-financing mechanisms.
3. Strengthen innovation incentives for women-led and youth-led cooperatives, promoting entrepreneurship and demographic renewal in rural communities.
4. Enhance monitoring and evaluation frameworks, including real-time dashboards and annual impact assessments at the regional level, to improve transparency and adaptive policy-making.
5. Promote "smart bioenergy" solutions based on agricultural residues and waste, balancing diversification with food security and biodiversity protection.
6. Invest in social infrastructure and care economies to improve quality of life, support vulnerable populations, and counteract demographic decline.
7. Encourage cooperative models and short supply chains to enhance the bargaining power of small producers and increase local value creation.

By pursuing these policy directions, Bulgaria can build on the achievements of the CAP and move toward a more balanced, inclusive, and resilient model of rural development. A place-based, data-driven approach that integrates economic, environmental, and social dimensions will be essential to achieving sustainable growth and improving the long-term vitality of rural regions.

## REFERENCES

Bulgarian National Statistical Institute (2023). *Rural Demography and Employment Survey*. <https://www.nsi.bg/statistical-data/8>



- Beluhova Uzunova, D., Ivanova, M., & Petkova, M. (2021). Direct Payments in Bulgaria – Trends and Perspectives. *Bulgarian Journal of Agricultural Science*, 27(5), 754–763.
- Beluhova Uzunova, R., Atanasov, D., & Shishkova, M. (2025). Direct Payments in Bulgaria – Trends and Perspectives. *Bulgarian Journal of Agricultural Economics and Management*, 64(3), 42–50.
- Beluhova Uzunova, R., Hristov, K., & Shishkova, M. (2019). Small farms in Bulgaria – Trends and Perspectives. *Agricultural Sciences*, 11(25).
- European Commission (2023). *EU CAP Indicators Dashboard*. [https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans/bulgaria\\_en](https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans/bulgaria_en)
- European Court of Auditors (2022). *CAP and Climate Targets: Special Report 16/2022*. <https://op.europa.eu/webpub/eca/special-reports/cap-and-climate-16-2021/bg/>
- Georgiev, M., Stoeva, T., & Dirimanova, V. (2023). The governance structure of agricultural policy in Bulgaria. *Bulgarian Journal of Agricultural Science*, 29(1), 12–25.
- Ivanov, P. (2022). Analysis of the political framework related to the provision of agro-ecological services in Bulgaria. *Bulgarian Journal of Agricultural Science*, 28(3), 456–467.
- Ivanov, S. (2025). Analysis of the political framework related to the provision of agro ecological services in Bulgaria. *Bulgarian Journal of Agricultural Economics and Management*.
- Ivanova, P. (2023). Land relations: social impacts and projections. *Bulgarian Journal of Agricultural Science*, 29(5), 524–535.
- Kirechev, D. (2023). Sources of financing for investments in agricultural holdings in Bulgaria – assessment of financial instruments. *Bulgarian Journal of Agricultural Science*, 29(5), 510–523.
- Ministry of Agriculture. *Agrarian Report 2024*.  
[https://www.mzh.government.bg/media/filer\\_public/2025/01/16/ad\\_2024\\_en.pdf](https://www.mzh.government.bg/media/filer_public/2025/01/16/ad_2024_en.pdf)
- Ministry of Finance. *Fiscal Strategy Report 2025*. [https://economy-finance.ec.europa.eu/economic-and-fiscal-governance/stability-and-growth-pact/preventive-arm/national-medium-term-fiscal-structural-plans\\_en#bulgaria](https://economy-finance.ec.europa.eu/economic-and-fiscal-governance/stability-and-growth-pact/preventive-arm/national-medium-term-fiscal-structural-plans_en#bulgaria)
- Patarchanov, P. (2019). Railway Transport in Regional and Local Development of the Rural Areas – Challenges and Opportunities. *SGEM International Multidisciplinary Scientific Conferences on Social Sciences and Arts*, Albena, Bulgaria. <https://doi.org/10.5593/sgemsocial2019/5.1/S21.083>
- Patarchanov, P., & Patarchanova, E. (2014). Contemporary theory and methodology in studies and development models of peripheral areas. *Journal of Settlements and Spatial Planning, Special Issue*, 3, 95–100.
- Strategic Plan for Agricultural and Rural Development 2023–2027.
- Stoeva, T., Dirimanova, V., & Georgiev, M. (2023). The trends, role and importance of extension services for the development of land relations in Bulgaria. *Bulgarian Journal of Agricultural Science*, 29(5), 536–548.
- Rural Development Programme 2014–2020 Summary (EU Factsheet). [https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development/country/bulgaria\\_en](https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development/country/bulgaria_en)
- National Programme for Reforms 2024, <https://www.minfin.bg/en/867>



**How to cite this article:**

Shlyakov, V. (2025). The Role of European Union's Agricultural Policy in the Development of Rural Areas in Bulgaria. *International Journal of Digital Research*, E-ISSN: 3033-179X; 1 (3): 53-71  
<https://doi.org/10.63711/ijdr.net20250306>

\*\*\*\*\*



# Historical and Contemporary Analysis of Climate Change and PM<sub>10</sub> Air Pollution in Plovdiv

Krasimir Stoyanov<sup>1</sup>, Galina Bezinska<sup>2</sup>, Ruslana Ivanova-Dobрева<sup>3</sup>

<sup>1</sup>Associate Professor, <sup>2</sup>Chief Assistant Professor, <sup>3</sup>BA Student  
<sup>1,2,3</sup>Department of Geography, Ecology and Environmental Protection  
Faculty of Mathematics and Natural Sciences  
South-West University “Neofit Rilski”, Blagoevgrad, Bulgaria  
ORCID ID’s: <sup>1</sup> 0000-0003-3920-2497, <sup>2</sup> 0000-0002-7111-4692

Corresponding Author: Krasimir Stoyanov, E-mail: [krasi\\_sto@swu.bg](mailto:krasi_sto@swu.bg)

<https://doi.org/10.63711/ijdr.net20250307>

## ABSTRACT

This study examines the interplay between climate change and fine particulate matter (PM<sub>10</sub>) pollution in Plovdiv, the second-largest urban and industrial centre in Bulgaria. Long-term climate data spanning 1976–2024, together with contemporary air quality records from the Kamenitsa and Trakia automatic monitoring stations for the period 2015–2024, were analysed. The results indicate a marked increase in annual mean temperature of approximately 1.5–2°C over the past five decades, accompanied by greater variability in precipitation, manifested through alternating droughts and short but intense rainfall events. PM<sub>10</sub> pollution persists as a major environmental challenge, with peak concentrations occurring during the winter months, primarily due to domestic solid-fuel heating and frequent temperature inversions. Exceedances of the EU and WHO daily limit value of 50 µg/m<sup>3</sup> are widespread. A strong correlation was observed between meteorological conditions and PM<sub>10</sub> dynamics: calm conditions and inversions facilitate particle accumulation, whereas precipitation and stronger winds exert a cleansing effect. The study underscores the need for improved monitoring, restrictions on solid-fuel heating, and the adoption of sustainable urban policies to reduce environmental and public health risks.

**Keywords:** Climate change, Plovdiv, Fine particulate matter (PM<sub>10</sub>), Air pollution, Sustainable development

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

Climate change and air pollution represent two of the most pressing environmental challenges across Europe. Plovdiv, Bulgaria’s second-largest city, is situated in a lowland basin that is particularly susceptible to temperature inversions, which in turn intensify episodes of air pollution. Rapid urbanisation, transport-related emissions, and the widespread use of solid fuels further contribute to frequent exceedances of PM<sub>10</sub> limit values. This article seeks to provide an integrated assessment of long-term climatic trends and recent PM<sub>10</sub> pollution dynamics in Plovdiv.

Air pollutants may be classified according to their origin, pathways of entry into the atmosphere, chemical composition, and physical state (Nikolova, 2008).

Among the most significant air pollutants are particulate matter (PM). Fine particulate matter is defined as PM<sub>10</sub> – particles with an aerodynamic diameter of 10 micrometres or less; PM<sub>2.5</sub> – particles with a diameter of 2.5 micrometres or less; and ultrafine particles (UFP) – particles with a diameter of 0.1 micrometres (100 nanometres) or less. These particles pose a serious threat to human health, as both their size and composition determine the degree of their impact on the body. Coarser particles are typically retained in the upper respiratory tract, whereas finer particles (below 2.5 µm) have a greater propensity to penetrate deeply into the respiratory system, where they may cause damage to lung tissue. It is well established that long-term exposure to elevated PM concentrations increases the risk of respiratory, cardiovascular, and other diseases (Petrova & Dimitrov, 2025).

According to analyses conducted by the European Environment Agency, a considerable proportion of the urban population in the EU is exposed to concentrations exceeding the established thresholds. Particulate matter (PM<sub>10</sub>) remains a persistent problem in densely urbanised areas. In 2024, the EU revised its air quality standards to align more closely with the recommendations of the World Health Organization. This revision introduced stricter limit values to be achieved by 2030. For PM<sub>10</sub>, the previous annual EU limit of 40 µg/m<sup>3</sup> was lowered to 20 µg/m<sup>3</sup> under Directive 2024/2881, thereby intensifying regulatory pressure in cities such as Plovdiv.

## LITERATURE REVIEW

In recent decades, research activity on climate change and air pollution in Southeastern Europe has increased significantly. A growing body of literature documents a persistent warming trend across the Balkan Peninsula. Heatwaves are becoming increasingly frequent and prolonged (Cheval et al., 2017; Djurdjević et al., 2024), while drought events are also occurring more often. These changes affect the entire region and are accompanied by shifts in precipitation patterns (Drenovski & Stoyanov, 2009, 2010; Velev, 2010; Rachev & Dimitrova, 2016). Urban areas are of particular concern, as local climatic conditions, high population density, and transport-related emissions exacerbate challenges related to the formation of urban heat islands and the deterioration of air quality (Gocheva-Ilieva et al., 2016; Stoimenova et al., 2017; Boras et al., 2025). The European Environment Agency (EEA, 2023) asserts that fine particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) continues to be the most critical pollutant in terms of its human health implications. Recent Bulgarian studies (Nikolova, 2008; Petrova & Todorov, 2025; Ivanov, 2017; Gosteva, 2021) highlight the strong influence of meteorological factors – including wind speed, temperature inversions, and precipitation – on the variability of particulate matter concentrations. Significant attention has also been devoted to the issue of air pollution in Bulgaria's largest cities, including Sofia, Plovdiv, Varna, Stara Zagora, and others (Gocheva-Ilieva et al., 2016; Ivanov, 2017; Health Effects Institute, 2022). In addition, particular attention is paid to particulate matter pollution resulting from the transport of Saharan dust (Evgenieva et al., 2024). The *National Climate Change Adaptation Strategy and Action Plan of the Republic of Bulgaria* (Ministry of Environment and Water, 2019) further emphasises the heightened vulnerability of urban areas to heat waves and air pollution episodes. Collectively, these studies provide a robust scientific foundation for integrated assessments that link long-term climate analyses with contemporary air quality monitoring.

## MATERIALS & METHODS

The present study is based on the following data sets: (a) climate data for temperature and precipitation (1976–2024) from NIMH, and PM<sub>10</sub> data (2015–2024) from the Kamenitza and Trakia monitoring stations. The statistical techniques employed include regression analysis, trend estimation, and correlation analysis between meteorological conditions and pollution levels. The data are compared with the standards set by the EU and the WHO.

The National Institute of Meteorology and Hydrology (NIMH) is the primary source of climate data. Mean monthly values of temperature (1977–2024) and precipitation (1976–2024) from the



Plovdiv station were utilised. To enable comparison and assess long-term trends in the distribution of these climatic elements, processed data were also drawn from the *Climatic Reference Book of the People's Republic of Bulgaria* (1959), the *Precipitation Reference Book* (1962), and the climatic reference volumes on individual elements published in the 1980s (Vols. 1–6).

The Regional Inspectorate of Environment and Water (RIEW) – Plovdiv is responsible for monitoring air quality in the Plovdiv region through the operation of two stations. Data were obtained from the [Executive Environment Agency \(ExEA\)](#) via the Information System for Public Access to Ambient Air Quality. The online [Information System for the Public on Ambient Air Quality](#) of the ExEA was also used as a supplementary data source. This platform provides hourly, daily, and annual average values for 13 meteorological indicators and air pollutants. For the purposes of this study, daily mean concentrations of PM<sub>10</sub> were extracted and processed from two Automatic Monitoring Stations (AMS) covering the period 2015–2024. These stations form part of the *National System for Environmental Monitoring (NSEM)*. Concurrently, data on temperature, wind direction, and wind speed were collated, amounting to approximately 30,000 records.

The AMS “Kamenitsa” is classified as an urban background station. It is located in the central part of the city and is predominantly surrounded by residential buildings, with moderate traffic intensity. The average hourly traffic flow in the area has been estimated at approximately 1900 motor vehicles (MV) (Municipality of Plovdiv, 2020).

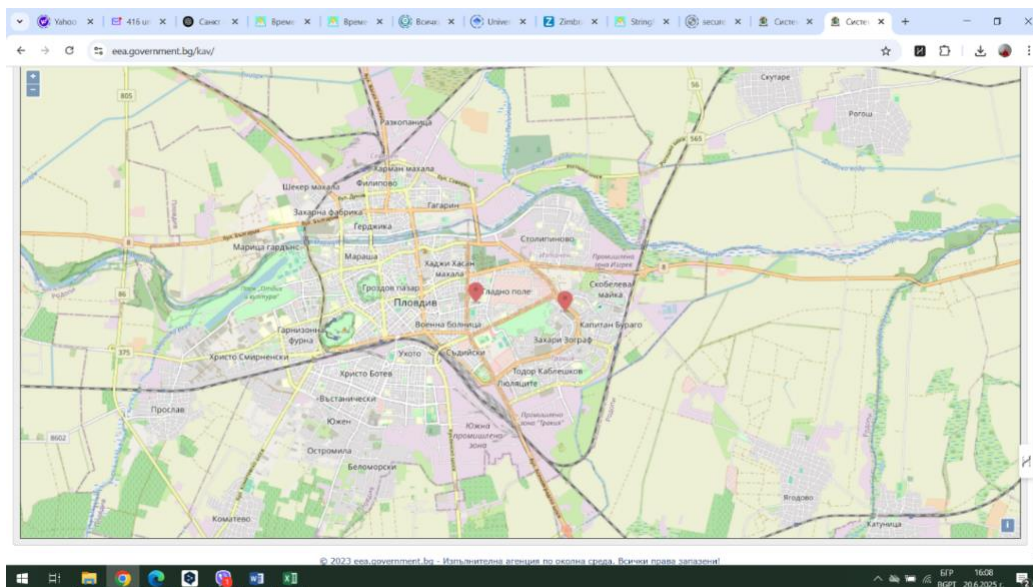


Figure 1. The geographical location of AMS Kamenitsa and AMS Trakia

The “Trakia” AMS is classified as a traffic monitoring site. It provides information on air pollution levels resulting from road traffic in close proximity to a high-traffic roadway. According to the Municipality of Plovdiv (2020), the average hourly traffic intensity near this site is approximately 2100 MV (fig. 1).

In this study, daily mean PM<sub>10</sub> data were collected and processed from AMS Kamenitsa over a ten-year period (2015–2024), and from AMS Trakia for the period 2016–2024; however, sporadic interruptions in data collection were observed. The dataset was analysed using standard statistical methods, including regression, correlation, and trend analysis. The results are presented in tables and figures.

## RESULTS & DISCUSSION

The city of Plovdiv is located within the transitional continental climate zone of Eastern Central Bulgaria. This region encompasses most of the lowlands along the Maritsa and Tundzha rivers and

borders the Continental-Mediterranean climatic region to the southeast (Velev, 2010). It represents the most extensive part of the transitional climatic zone. According to Sabev and Stanev (1959), the area is classified as part of the transitional-continental climatic sub region of the European-continental climatic region. In this region, the continental character of the climate is considerably moderated compared to the Danube Plain, as reflected in a lower annual temperature amplitude, primarily due to milder winters.

**Temperature trends**

As shown in Table 1, mean monthly and annual temperatures recorded at the Plovdiv station are presented for four distinct periods. The first period covers 40 years, while the remaining three span 30 years each. Two of these periods correspond to reference climatological normal adopted by the World Meteorological Organization (WMO). Table 2 displays the differences in average temperatures between the initial and the most recent period. A clear warming trend is evident across all months. The most pronounced increase is observed in January, with a rise of 1.9°C, equivalent to 0.29°C per decade. For February, March, and August, the increase is 1.7°C. The smallest change is recorded in November, at 0.3°C. Seasonal analysis indicates that the most substantial warming has occurred in summer, followed by winter, spring, and autumn.

Table 1. Average monthly and annual temperatures in Plovdiv across different time periods

Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Год.
1995-2024	1,5	3,9	7,7	12,8	17,9	22,3	24,7	24,4	19,2	13,1	7,7	2,8	13,1
1991-2020	1,1	3,3	7,7	12,7	17,9	22,1	24,4	24,1	19,1	13,2	7,5	2,4	13,0
1961-1990	0,3	2,8	6,8	12,2	17,1	20,9	22,9	22,0	18,4	12,4	7,0	2,4	12,1
1931-1970	-0,4	2,2	6,0	12,2	17,2	20,9	23,2	22,7	18,3	12,6	7,4	2,2	12,0

Table 2. Difference in monthly temperatures in Plovdiv between two periods

Difference, C°	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average
1995-2024 /1931-1970	1,9	1,7	1,7	0,6	0,7	1,4	1,5	1,7	0,9	0,5	0,3	0,6	1,1

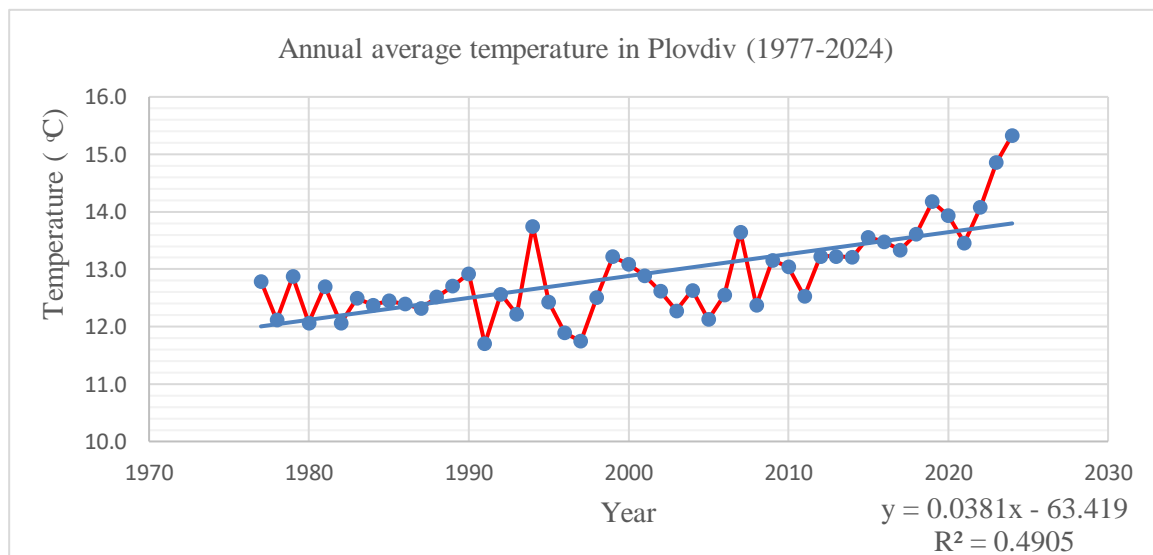


Figure 2. Annual average temperature in Plovdiv (1977–2024).

Figure 2 shows the change in mean annual temperature over the past 48 years. Linear regression was applied to assess the presence of a statistically significant trend. The graph reveals that during the initial decades (1977–2000), temperatures fluctuated around 12–13 °C, with minor variations and no clear trend. From approximately 2000–2005 onwards, a gradual but consistent increase in mean annual

temperature is observed. After 2015, this increase becomes more pronounced and accelerated, with recent years (2022–2024) reaching approximately 14.5–15 °C. Overall, the data indicate an upward trend in mean annual temperatures in Plovdiv for the period 1977–2024, with an estimated warming of about 1.5–2 °C. This trend, confirmed through linear regression, corresponds to an average increase of 0.038 °C per year (approximately +1.8 °C over the 47-year period), as indicated by the analysis. Despite the presence of some cooler years, the overall pattern is one of sustained warming.

The graph illustrates a long-term warming trend in Plovdiv's climate, particularly evident since 2000 and accelerating after 2015. Annual temperatures exceed the climatic norms for the period 1961–1990 by more than 1.5–2.0 °C.

The linear regression analysis indicates an average decadal increase of 0.38 °C over the period 1977–2024. The cumulative effect over this 48-year period is approximately +1.8 °C, which aligns with the visual increase observed in the graph. This variability can be attributed to two main factors: a long-term warming trend and short-term fluctuations driven by processes such as urbanisation, atmospheric circulation, and local meteorological conditions.

### Precipitation

The annual precipitation totals from 1976 to 2024 demonstrate a high degree of variability, characterised by alternating periods of drought and short-lived extreme rainfall events. No discernible long-term trend has been identified.

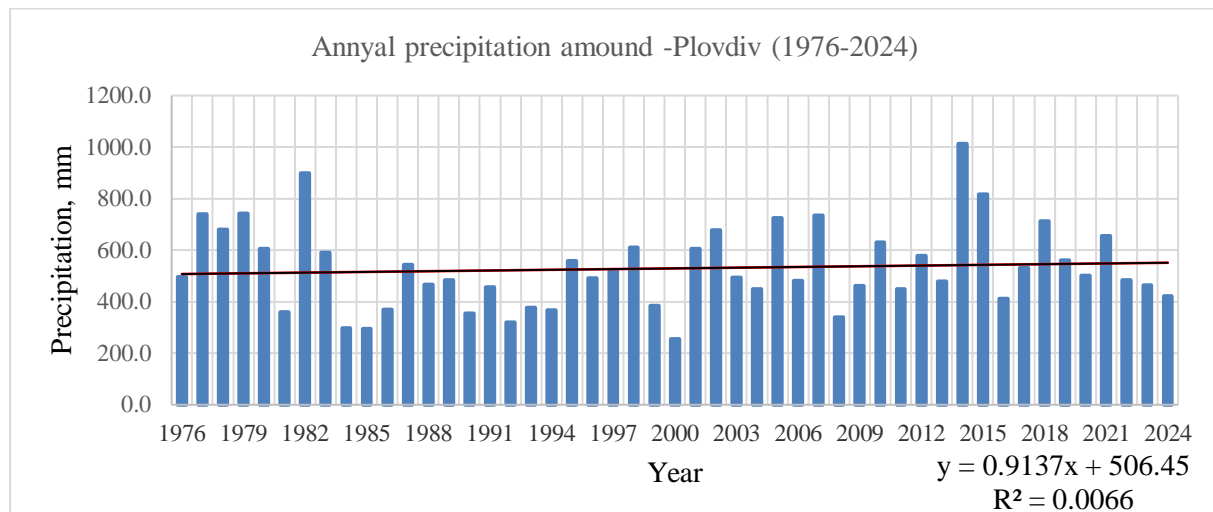


Figure 3. Annual precipitation in Plovdiv (1976–2024)

Precipitation is a climatic element characterised by considerable spatial and temporal variability. Various time periods were analysed, the earliest of which begins in 1896. Although significant fluctuations in annual precipitation totals have been recorded over the years, no long-term trend is evident (Fig. 3).

Precipitation patterns in Plovdiv for the period 1976–2024 exhibits a very weak increasing trend of approximately 0.9 mm per year, which is statistically insignificant ( $R^2 = 0.0066$ ). Nevertheless, variability is pronounced, with annual totals ranging from below 300 mm to over 900 mm. These results point to increasing irregularity in precipitation distribution rather than a clear long-term trend.

Annual precipitation totals vary considerably, ranging from less than 300 mm in the driest years to over 1000 mm in the wettest. The linear trend demonstrates a marginal positive slope (+0.91 mm/year, or approximately +9 mm/decade), although the coefficient of determination ( $R^2$ ) is only 0.0066. The Mann–Kendall test was applied to annual precipitation data for Plovdiv (1976–2024). The test statistic did not indicate a statistically significant trend ( $p > 0.05$ ), confirming that variability is primarily driven by interannual fluctuations rather than a long-term directional change. This suggests that, over the long

term, no persistent trend in annual precipitation can be observed, with variability largely governed by interannual and decadal climatic oscillations.

Over the past two decades (2000–2024), an increase in precipitation amplitude has been observed, characterised by more frequent dry periods alternating with short-lived but intense rainfall events. This pattern is consistent with broader trends reported in the Mediterranean and Balkan regions, where climate change is driving a shift towards more erratic precipitation regimes.

As illustrated in Table 3, there are noticeable variations in the intra-annual distribution of precipitation. For example, the driest month of the year differs across the analysed periods, with February, March, August, or November appearing as the minimum in different years. It is important to note that the precipitation totals for these driest months differ only slightly – typically by 1–2 mm. Regarding the month with the highest precipitation, it is consistently either May or June, with minimal differences in the recorded values.

Table 2. Mean monthly and annual precipitation totals (mm) at Plovdiv station for different periods

Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
1995-2024	44,1	36,1	48,0	42,4	59,8	61,0	50,6	35,9	44,4	47,9	33,7	48,0	551,8
1991-2020	39,1	36,2	47,8	41,2	58,9	58,3	51,4	34,4	43,8	48,0	35,7	43,0	537,6
1931-1985	42	32	38	45	65	63	49	31	35	43	47	49	539,0
1896-1945	39	32	36	42	54	62	47	35	36	40	48	44	515,0

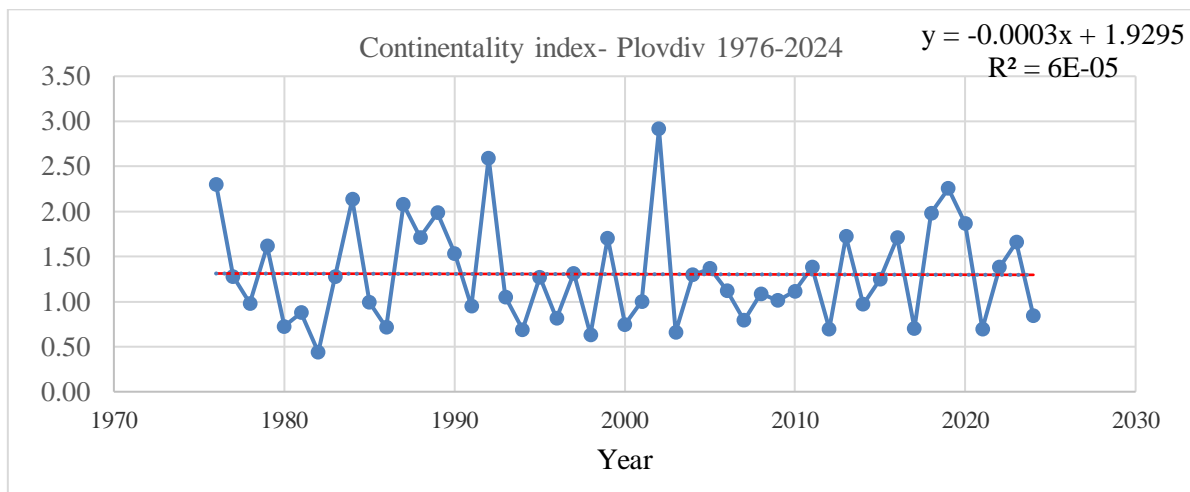


Figure 4. Continuity index based on annual precipitation (1976-2024)

An indicator of prevailing precipitation distribution is the Continuity Index (CI) (Fig. 4), calculated as the ratio of precipitation totals during the spring–summer period to those in the autumn–winter period. This index is used to assess the dominant climatic influence: continental, characterised by a predominance of spring–summer precipitation, or Mediterranean, marked by higher precipitation in autumn and winter. As shown in Fig. 4, the value of  $y$  ( $-0.0003$ ) is extremely close to zero, indicating the absence of any discernible long-term trend. Moreover, the coefficient of determination ( $R^2$ ) confirms that the trend is not statistically significant. Interannual variability is pronounced, precluding the existence of a clear linear tendency. Values range from approximately 0.45 (indicating very wet autumn and winter seasons) to above 3.0 (wet spring and summer periods). These findings highlight the significant influence of specific atmospheric conditions in individual years.

Over the past five decades, there has been no discernible trend towards either a more continental or a more Mediterranean precipitation regime. The distribution of precipitation remains highly variable,

predominantly shaped by natural climatic fluctuations rather than by any consistent long-term trend. Years with unusually high or low Continentality Index (CI) values are most likely the result of extreme synoptic conditions, such as very wet summers or winters.

The main conclusion drawn from the analysis is that no stable long-term trend in precipitation amounts can be identified. However, the observed increase in variability amplifies the risk of both droughts and localised flooding. These dynamics have a direct impact on water resources, agriculture, and ecosystems in the Plovdiv region.

**PM10 Air Pollution**

The mean PM<sub>10</sub> concentration at the Kamenitsa station is 35.08 µg/m<sup>3</sup>, while at AMS Trakia it is 43.25 µg/m<sup>3</sup>. Considerable variations are observed both between years and across months. These are expressed as follows:

High values are recorded during the winter months, with a peak in January, and low values during the warmer half of the year (Fig. 5; Table 4). The months from April to September show similar levels, with the lowest value occurring in May. As seen in Figure 5, the annual course of pollution at the two stations is identical. The lowest concentrations are recorded in May. A gradual increase begins in August–September.

Table 3. Monthly mean concentrations of PM<sub>10</sub> (2015–2024)

Stations	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year.
AMS Kamenitsa	54,95	48,55	34,21	26,49	22,63	24,28	24,46	26,2	28,78	35,46	44,97	49,94	35,08
AMS Trakia	64,95	60,31	42,37	32,3	29,5	30	30	31,64	33,59	44,75	57,41	61,27	43,25

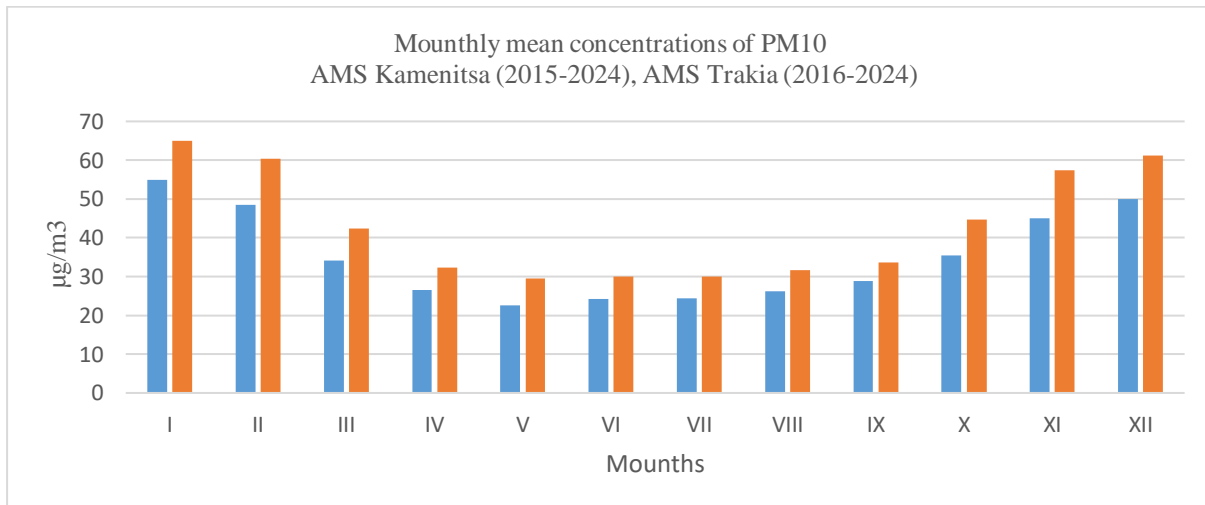


Figure 5. Monthly mean concentrations of PM<sub>10</sub>– AMS Kamenitsa (blue) and AMS Trakia (red)

A direct relationship between meteorological conditions and particulate matter pollution, as well as other air pollutants, has been established (Gosteva, 2021). Very low average wind speeds have been recorded at the monitoring stations: 0.61 m/s at AMS Kamenitsa and 0.80 m/s at AMS Trakia. This can be attributed to the fact that wind speed is measured not at the standard height of 10 meters, but at approximately 2 meters above ground level, where speeds are significantly lower. An additional contributing factor is the dense urban development; as reduced wind speed is a characteristic feature of the urban climate.

Wind direction remains almost constant throughout the months and seasons, influenced by local conditions such as street orientation and the presence of buildings. At the Kamenitsa station, the prevailing wind direction is WSW (238°), while at the Trakia station it is SSE (152°).

A clear correlation has been observed between wind speed and pollution levels. Figure 6 illustrates this relationship for February 2017 at AMS Trakia. The Pearson correlation coefficient between PM<sub>10</sub> concentration and wind speed is  $r = -0.63$ , indicating a moderately strong negative relationship. At the highest PM<sub>10</sub> concentrations (200–330  $\mu\text{g}/\text{m}^3$ ), wind speeds are very low (0.39–0.64 m/s), whereas at higher wind speeds (above 2 m/s), PM<sub>10</sub> values are considerably lower (e.g., 32–66  $\mu\text{g}/\text{m}^3$ ).

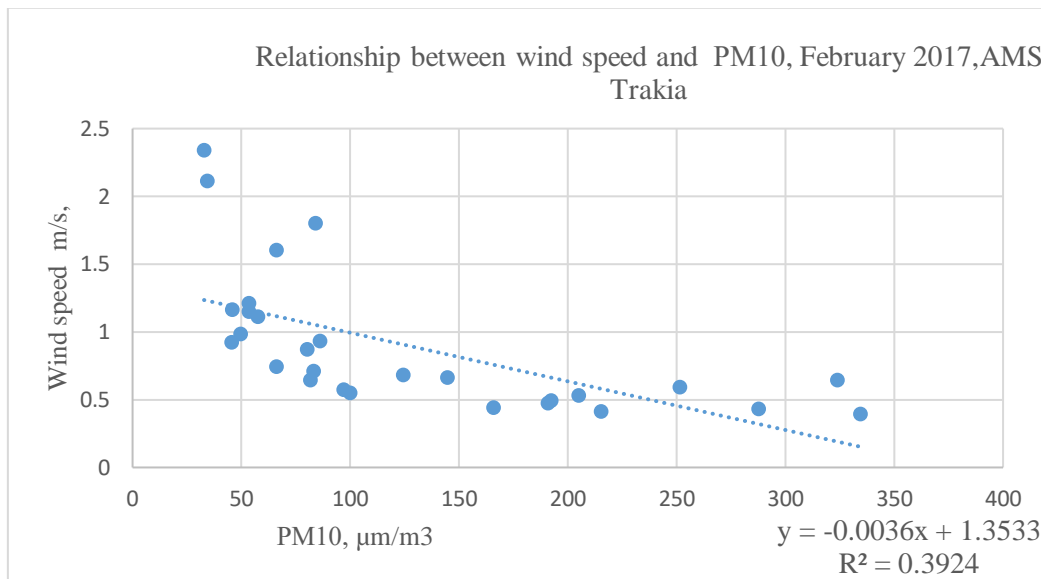


Figure 6. Relationship between wind speed and PM<sub>10</sub> concentrations in February 2027, AMS Trakia

In the obtained regression analysis, where  $X = \text{PM}_{10}$  and  $Y = \text{wind speed (WS)}$ , the equation reflects how changes in PM<sub>10</sub> concentrations correspond to variations in wind speed. The slope is relatively small ( $-0.0036$ ), as it represents the rate of change in WS per unit increase in PM<sub>10</sub> concentration.

A clear warming trend is evident, as indicated by the upward trajectory of the trend line. The linear trend is  $+0.038\text{ }^\circ\text{C}$  per year, corresponding to approximately  $+1.8\text{ }^\circ\text{C}$  over 47 years. The coefficient of determination is  $R^2 = 0.49$ , suggesting that nearly 50% of the variance is explained by the linear trend, indicating a statistically meaningful relationship.

Since 2015, the rate of warming has accelerated, with average annual temperatures exceeding  $14\text{--}15\text{ }^\circ\text{C}$  in the last three years. Plovdiv is undergoing climate warming, increasingly evident over the past two decades. This trend aligns with broader patterns observed across Bulgaria and South-eastern Europe. Rising temperatures increase the likelihood of more frequent and prolonged heatwaves, with serious implications for public health and urban resilience. The most recent years are among the warmest recorded for the analysed period.

Precipitation data reveal substantial inter-seasonal and inter-annual variability, with some years receiving less than 300 mm, and others exceeding 900–1,000 mm. This highlights a growing irregularity in the precipitation regime, which is more critical than the presence or absence of a long-term trend.

Rather than a clear directional shift, the pattern reflects an alternation of dry and wet years, consistent with the broader climatic instability in southern Bulgaria, influenced by the cyclical nature of Mediterranean cyclones and drought events. In the context of climate change, the increase in extremes – years that are either very dry or very wet – is more important than changes in the average trend.

## CONCLUSION

1. The climate of Plovdiv has warmed substantially (+1.5 to 2 °C) since the 1970s. This is reflected in a clear and statistically significant upward trend in temperature.
2. Precipitation patterns are unstable, alternating between dry periods and heavy rainfall. Annual totals and seasonal distribution do not exhibit a consistent long-term trend, with variability largely driven by natural atmospheric processes.
3. There is a clear divergence between temperature and precipitation trends: while temperatures continue to rise, precipitation remains within the range of natural fluctuations. This may affect the region's water balance and contribute to more frequent droughts and heatwaves.
4. PM<sub>10</sub> pollution remains a serious environmental issue, particularly during winter. In several years, annual average concentrations exceeded the regulatory limit of 40 µg/m<sup>3</sup>, pointing to a persistent air quality problem. During the winter months (December to February), PM<sub>10</sub> levels often rise sharply, frequently surpassing the daily limit of 50 µg/m<sup>3</sup>. The main cause is domestic heating with solid fuels, combined with adverse meteorological conditions such as temperature inversions and low wind speeds. In contrast, concentrations during the summer months are relatively low, confirming the strong seasonal character of the pollution.
5. Meteorological factors – especially wind speed, precipitation, and inversions – have a marked effect on PM<sub>10</sub> levels. A clear negative correlation is observed between wind speed and particulate matter concentrations, with weaker winds favouring the accumulation of pollutants.
6. Addressing this issue requires integrated measures, including cleaner heating technologies, sustainable transport solutions, and improved air quality monitoring.

This study highlights the need for an integrated approach to climate and air quality in support of sustainable urban planning in Bulgaria.

## REFERENCES

- Boras, M., Herceg-Bulić, I., & Žgela, M. (2025). Urban heat load in a small Mediterranean city in recent, extreme, and future climate conditions: A case study for the city of Dubrovnik. *International Journal of Climatology*, 45(3), e8728. <https://doi.org/10.1002/joc.8728>
- Cheval, S., Dumitrescu, A., & Birsan, M. V. (2017). Variability of the aridity in South-Eastern Europe over 1961–2050. *Catena*, 151, 74–86. <https://doi.org/10.1016/j.catena.2016.12.011>
- Djordjević, V., Stosic, B., Tošić, M., Lazić, I., Putniković, S., Stosic, T., & Tošić, I. (2024). Analysis of recent trends and spatiotemporal changes of droughts over Serbia using high-resolution gridded data. *Atmospheric Research*, 304, 107376. <https://doi.org/10.1016/j.atmosres.2024.107376>
- Drenovski, I., & Stoyanov, K. (2009). About some anomalies in the precipitation regime in Bulgaria. In *Proceedings of the International Scientific Conference FMNS* (pp. 279–284). Blagoevgrad: South-West University.
- Drenovski, I., & Stoyanov, K. (2010). Changes in the precipitation regime in Bulgaria in recent years. In *Proceedings of the International Conference "Geography and Regional Development"* (pp. 238–242). Sofia: NIGGG–BAS.
- European Environment Agency (EEA). (n.d.). Home page. Retrieved September 22, 2025, from <https://www.eea.europa.eu>
- Evgenieva, T., Vakareeva, E., Gurdev, L., & Dreischuh, T. (2024). Identification of Saharan-dust intrusions over Sofia, Bulgaria, using near-ground PM<sub>10</sub> and PM<sub>2.5</sub> mass concentration measurements. *Aerosol and Air Quality Research*, 24(6), 230304.
- Executive Environment Agency. (n.d.). *Information System for Public Access to Ambient Air Quality*. <https://eea.government.bg/kav/about/>
- Gocheva-Ilieva, S., Iliev, I., Ivanov, A., Stoimenova, M., & Voynikova, D. (2016). Stochastic univariate and multivariate time-series analysis of PM<sub>2.5</sub> and PM<sub>10</sub> air pollution: A comparative case study



- for Plovdiv and Asenovgrad, Bulgaria. *AIP Conference Proceedings*, 1773(1), 040001. <https://doi.org/10.1063/1.4965008>
- Gosteva, L. (2021). *Influence of some meteorological factors on urban air pollution* [Author's abstract of dissertation, University of Forestry]. (in Bulgarian)
- Health Effects Institute. (2022). *Air quality and health trends in Bulgaria: Special report on the state of global air*. Boston, MA: Health Effects Institute. ISSN 2578-6881. (in Bulgarian)
- Ivanov, K. (2017). *Climatic features and air quality in the Pernik Basin* [Author's abstract of dissertation]. Sofia. (in Bulgarian)
- Kalcheva, R. (Ed.). (1962). *Precipitation handbook of the People's Republic of Bulgaria*. Sofia: NI. (in Bulgarian)
- Koleva, E., & Peneva, M. (Eds.). (1990). *Climatic handbook: Precipitation in Bulgaria*. Sofia: BAS. (in Bulgarian)
- Kyuchukova, M. (Ed.). (1979–1983). *Climatic handbook of the People's Republic of Bulgaria* (Vols. 2–4). Sofia: BAS. (in Bulgarian)
- Municipality of Plovdiv. (2020). *Report on the impact of ambient air on the health of the population of Plovdiv in 2019*. Plovdiv: Municipality of Plovdiv. (in Bulgarian)
- Nikolova, N. (2008). *Air pollution and monitoring*. Sofia: Pensoft. (in Bulgarian)
- Petrova, D., & Todorov, N. (2025). Dynamics of particulate matter pollution in the transport microenvironment in Burgas. In *II National Scientific Conference on the Environment* (pp. 115–116). Sofia: NIMH.
- Rachev, N., & Dimitrova, D. (2016). Changes in mean temperature and precipitation in Bulgaria for the period 1995–2012. *Annual of Sofia University, Faculty of Physics*, 109, 1–25. (in Bulgarian)
- Republic of Bulgaria, Ministry of Environment and Water. (2019). *National Climate Change Adaptation Strategy and Action Plan*. Sofia. (in Bulgarian)
- Sabev, L. (Ed.). (1959). *Climatic handbook of the People's Republic of Bulgaria*. Sofia: NI. (in Bulgarian)
- Stoimenova, M., Iliev, I., Gocheva-Ilieva, S., Ivanov, A., & Voynikova, D. (2017). Regression-trees modelling and forecasting of PM<sub>10</sub> air pollution in urban areas. *AIP Conference Proceedings*, 1895(1), 030005. <https://doi.org/10.1063/1.5007364>
- Velev, S. (2010). *The climate of Bulgaria*. Sofia: Heron Press. (in Bulgarian)

**How to cite this article:**

Stoyanov, K., Bezinska, G., & Ivanova-Dobrevna, R. (2025). Historical and contemporary analysis of climate change and PM<sub>10</sub> air pollution in Plovdiv. *International Journal of Digital Research*, Vol. 1 (3): 72–81. <https://doi.org/10.63711/ijdr.net20250307>

\* \* \* \* \*



# Tannins: Plant-Derived Polyphenols That Enhance Skin Healing

Mateus Domingues de Barros<sup>1</sup>; Rebeca Xavier da Cunha<sup>1</sup>; João Ricardhis Saturnino de Oliveira<sup>1</sup>; Ana Paula Sant'Anna da Silva<sup>1</sup>; Layza Fernanda Gomes Bezerra<sup>1</sup>; Vera Lúcia de Menezes Lima<sup>1</sup>

<sup>1</sup>Laboratório de Lipídios e Aplicações de Biomoléculas em Doenças Prevalentes e Negligenciadas. Departamento de Bioquímica, Centro de Biociências, Universidade Federal de Pernambuco, Avenida Professor Moraes Rego, 1235, CEP 50670-901 Recife, PE, Brasil. <sup>1</sup>Laboratory of Lipids and Applications of Biomolecules in Prevalent and Neglected Diseases. Department of Biochemistry, Center for Biosciences, Federal University of Pernambuco, Avenida Professor Moraes Rego, 1235, Zip Code 50670-901 Recife, PE, Brazil

Corresponding Author: Mateus Domingues de Barros, E-mail: [mateusdb1@gmail.com](mailto:mateusdb1@gmail.com)

<https://doi.org/10.63711/ijdr.net20250308>

## ABSTRACT

In view of the healing process, factors such as depth, length and microorganisms infection can delay cicatrization, requiring the search for therapeutic alternatives, such as plant-derived metabolites. Tannins are secondary metabolites constituents of plants whose action on wounds is the most reported. The present work aims to do an exploratory descriptive literature review of tannins action as a therapeutic agent in wound healing through different mechanisms. Tannins work by forming a film on the lesion, creating an environment favorable to cell anticipation and extracellular matrix agents such as collagen and elastin, also having antioxidant and anti-inflammatory action. This polyphenol can adapt to different conditions according to their specificity and degree of aggression, thus proving to be superior to conventional means that have already been eliminated, leading to a brief discussion about these mechanisms that act synergistically during the healing process assisting in the development of new therapies.

**Keywords:** *Natural products, Healing, Polyphenols, Secondary metabolites*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

Skin is the largest organ of the human body serving as a primary barrier against biological agents such as viruses, bacteria and fungi, physical elements such as ultraviolet radiation and chemicals such as corrosive materials [37, 99]. In view of this, the skin tissue needs balance in response to stress or injury, and this process is then called healing, which is divided into 3 phases: inflammation, proliferative and remodelling, which are intrinsically correlated [6]. It is estimated that the annual expenditure on stitches for skin wounds reaches more than 28 billion dollars in many countries according to the world health organization (WHO), thus highlighting the importance of new treatments that are suitable

according to each clinical condition and its specificity, since particularities such as the presence of chronic and resistant diseases can make hospitalization imminent and treatment lasting, with greater expense, physical and emotional exhaustion [105].

According to the health insurance system in the United States of America (USA), Medicare, the value alone exceeds more than 40 billion annually in the outpatient service, which tends to increase as a result of hospitalizations and increased life expectancy [73]. In Brazil, public spending on treatments aimed at healing tends to increase with treatment time and the material used can reach approximately R\$ 293.00/person in coverage granted in a short period of time, varying according to location, availability of resources, and people [13]. In an attempt to avoid costly public health spending on the treatment of wounds, which is sometimes ineffective, there are countless studies that aim to improve the healing process.

One of the many lines of research is the use of plant media, an age-old practice employed by many peoples, but which requires scientific proof of its efficacy and safety [12, 117]. Scientific research on medicinal plants is mainly focused on their constituents and control of action in healing, and one of the groups of secondary metabolites most associated with healing potential are the tannins that are part of the group of polyphenols [8, 88, 113, 81]. Tannins are found in several plants, and their relationship with healing in *Punica granatum* [43], *Terminalia arjuna* [103] has already been well elucidated and *Bauhinia unguolata* [95] which acts through all stages of tissue preparation by stimulating tissue cells, fibroblasts, collagen and neutrophils [67]

Tannins are divided according to their resistance or not to hydrolysis, thus being classified as condensed and hydrolysable, respectively. They have anti-inflammatory, antimicrobial, antioxidant and vasoconstrictor action already well reported in the literature. Condensed tannins are used therapeutically because of their easy binding to protein structures, conferring broad biological activity and greater permanence in the tissue [69, 45, 102]. These metabolites can be extracted from plant tissues by the most different methods of extraction methods by solvents such as methanol, ethyl acetate and ethanol [96, 44, 30]. The present work aims to gather and integrate information on the action of tannins during the healing process in cutaneous wounds, and/or locally depending on the route of administration, as well as to evaluate the current scenario of bioprospecting these as a new therapeutic alternative in the treatment of wounds.

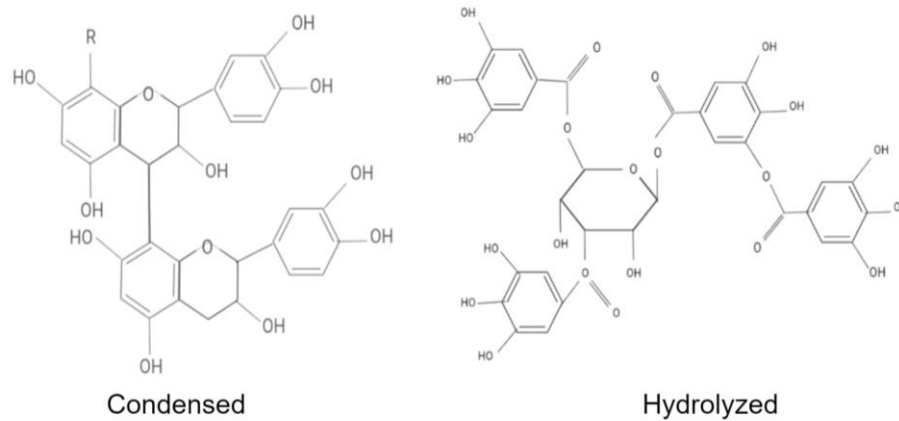
## METHODOLOGY

A literature review was carried out, with a descriptive and exploratory character. A literary survey of works published between the years 2003 - 2023 in Portuguese, Spanish and English, in the main databases of scientific works, Scielo, Google Scholar, Springerlink, Pubmed and Lilacs, being them: taninos (tannins/taninos), cicaytização (healing tannins/cicatrización), condensed tannins (condensed tannins/taninos condensados), fração rica em taninos na cicatrização (fraction rich in tannins in wound healing/fracción rica en taninos en cicatrización) and medicinal plants (medicinal plants /plantas medicinales). Emphasis was given to the direct action of tannins in all phases of healing, highlighting their influence and action pathways and those studies that do not prove this direct relationship are not included in this review.

## ORIGIN, CHARACTERISTICS AND BIOLOGICAL ACTION OF TANNINS

Tannins are part of the large group of natural compounds, the polyphenols. In their structure, they have hydroxyls connected to aromatic rings and are subdivided into hydrolyzable and condensed (Figure 1) [2]. Condensed tannins, mainly, have the ability to easily bind to protein complexes and polysaccharides in mucous membranes and tissues through hydrogen bonds, which makes them widely used in the commercial in the production of wines and leather tanning, which is quite profitable in those obtained by its large-scale performance [36, 24]. Tannins have a high adhesion index and molecular weight, especially condensed ones, which add what adds astringency to wines improves their flavor and what also aids in the healing of deep or deep wounds [105,113].

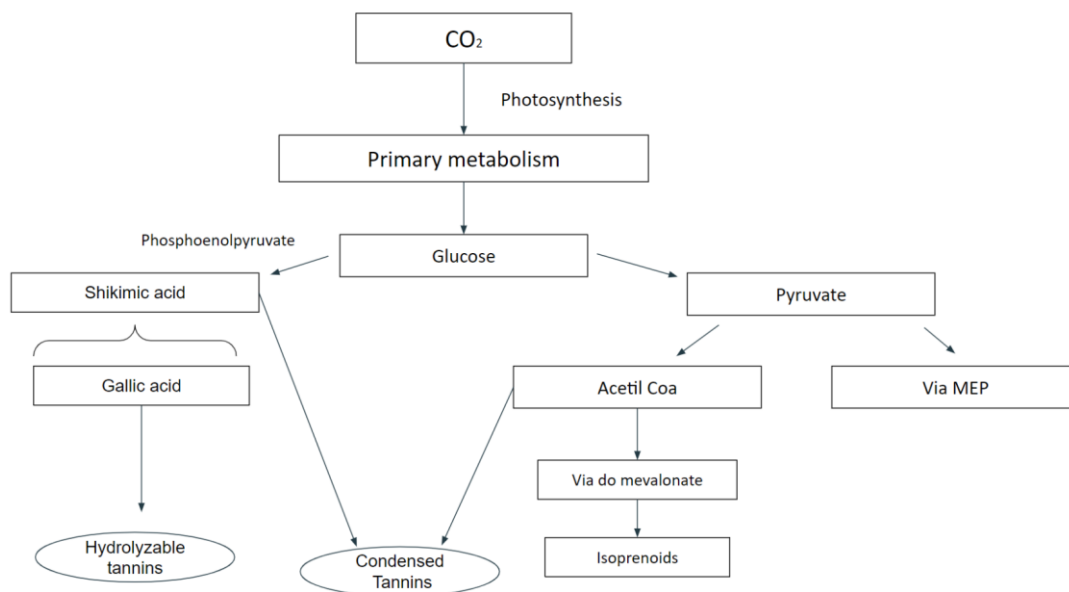




**Figure 1.** Representation of the structure of the main tannin groups

The synthesis of tannins occurs mainly in organelles derived from chloroplasts and are located in waxes that occur in plants and vacuoles [25]. Two pathways are responsible for its formation, namely the acid pathway, with the union of phosphoenolpyruvate with erythrose 4-phosphate which is divided into 3 phases: galloylation, generation of gallotannins and emission of galioid residues [86,104 , 16]. This union can generate gallic and ellagic acid with enzymatic action, having 2 main representatives of gallotannins and ellagitannins with influence on antioxidant activity and on the aging process by shortening telomeres [86,102].

The other is the acetate malonate route, highlighted in nutrition research, which is the precursor of flavan-3-ol, it has two phases for the formation of tannins, namely, glycosylation, where sugars are added to proteins and lipids forming glycoproteins structured and oligomerization with linkage of two or more polypeptide chains [104]. Tannins, in addition to originating from plants, can also be produced artificially using naphthalenes, crucibles and other superior hydrocarbons as primary ingredients [103, 113].



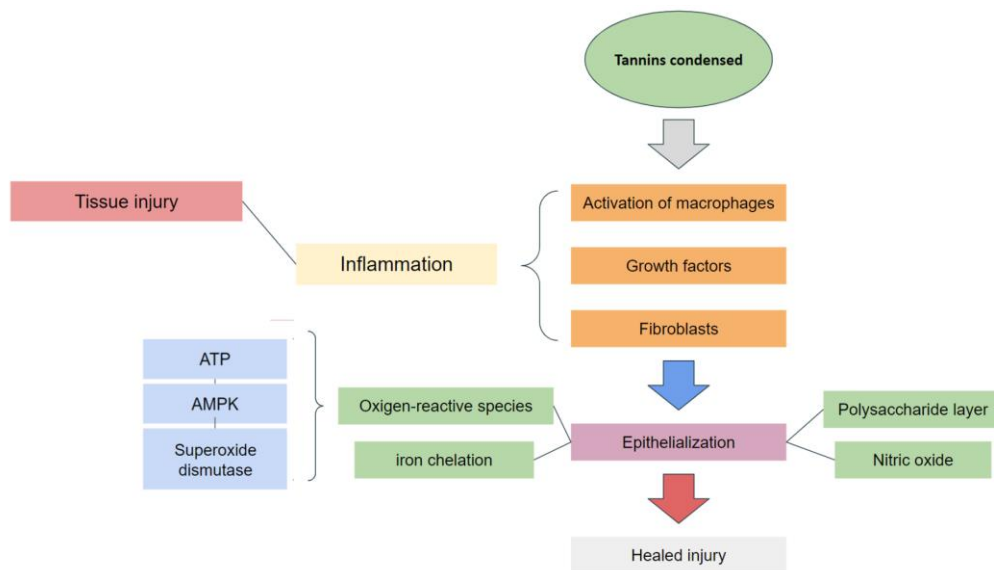
**Figure 2.** Reaction chain for the synthesis of hydrolyzable and condensed tannins.

Tannins can be found in various parts of plants such as roots, leaves, fruits with a greater proportion in the bark [86]. The secondary metabolites of plants, including tannins, can undergo changes due to changes in temperature, tension force and storage, however, it is seen in the literature that they do not change in their contents in order to survive the seasons of the year, but with greater ratio in protection and post storage [114]. Its ingestion takes place with the use of water or organic solvents such as methanol and ethanol, it is worth noting that the quality of the extract rich in tannins depends on factors such as the duration of the process and order of application of the solvents, since the constituents of the plant can interfere with the presence of high levels of tannins to be used in different clinical conceptions [25].

It is evidenced that the absorption of ingested tannins occurs normally despite its high molecular weight, being a dietary component metabolized by the intestinal microflora composed of bacteria whose reaction products are similarly phenyl valeric, phenylpropionic, phenylacetic and benzoic acid with systemic effect and subsequently excreted in the colon by two lactones conjugated by glucuronic acid [70]. It is observed that if consumed excessively, tannins form non-absorbable complexes with proteins, sugars, digestive enzymes, metal ions and vitamins (A, B12), which reduces their nutritional value [56] and increases the availability of oxidative and nutritive agents [111, 103].

The consumption of tannins also acts on internal lesions such as gastric ulcers by increasing the cytoprotection of the mucosa, however in deep gastric lesions beyond the epithelium, in the connective and smooth tissue, the time of use may be longer, adapting according to the state of patient's health, like those with chronic diseases [108, 104, 102, 57], however, it is worth mentioning that its safe dosage according to the American Federal Drug Administration (FDA) is 100 mg/kg a day with a minimum frequency of use, and cannot be used indiscriminately because it causes severe damage to the function of organs such as the liver [115].

In topical application, tannins can act by stimulating endogenous factors at all stages of healing [84]. These polyphenols act in the inflammatory phase, helping from homeostasis, with fibrin formation, to the recruitment of inflammatory mediators and growth factors such as tumor necrosis alpha (TNF- $\alpha$ ), platelet-derived growth factor (PDGF), fibroblastic growth (FGF) and transforming growth factor (TGF). In this process there is also the activation of defence and elaborated cells such as monocytes, lymphocytes and keratinocytes in addition to essential proteins such as elastin, ordering the tissue to its initial state [89, 28]. Due to its astringent property, tannins form complexes with proteins or polysaccharides that also create a protective physical barrier under the lesion, protecting against bacteria, free radicals and possible cell that give rise to various neoplasms [67, 46].



**Figure 3.** Tissue healing process using condensed tannins with representation of the main pathways of action.

In the proliferative phase of wound healing, tannins aid in the chemotaxis of growth factors, stimulating collagen and forming new blood vessels [81]. The action of tannins reaches a peak on the 7th day of tissue healing, which corresponds to a proliferative phase. However, wound characteristics such as: size, friction and amount of exudate can interfere with the closing time of its edges [102, 87]. Among the types of tannins available for consumption and administration (Figure 2) they are largely related to the healing process due to their resistance to hydrolysis, which in turn allows for a longer residence time and tissue response in addition to having low toxicity [95].

The non-use of topical formulations, hydrogels, creams and gels, with the addition of tannins is determinant that their physical/chemical characteristics provide a more accelerated permeation adapting to humidity, an essential factor in angiogenesis, a fundamental process for tissue oxygenation [61]. Its greatest use in the treatment of injuries concerns the use in spongy and gelatinous format for the membrane or in teas with the benefit of non-toxicity by the report of more traditional communities in the interior of Brazil, mainly in the Northeast [69]. In the use of hydrogels, tannic acid has been encouraged as it promotes stability in solutions that are crosslinked controlled, a factor that further drives its use in emulsions [66].

Tannins have vasoconstrictor, anti-inflammatory, antimicrobial properties, use in healing cuts or immunosuppressive diseases in traditional communities [88]. In view of its clinical potential, topical use at low concentrations has been highlighted for wound healing [76]. In addition to healing, research on affected problems has enormous prominence, such as combating the replication of the HIV virus [115] and diabetes [63].

## TANNIN EXTRACTION METHODS

Due to their heterogeneous nature, the yield, purity and composition of these polyphenols are dependent on parameters such as: natural source, collection technique and environmental conditions so that there is a better inheritance of these plant constituents [45]. Several organic solvents are used to extract tannins from natural tissues such as twigs, leaves and bark, most of which are methanol (MEOH), dichloromethane petroleum ether (DCM), ethanol (ETOH) and ethyl acetate, which provided higher yields, but the use of n-hexane, ether and petroleum, which are non-polar, are also used along with chloroform [104,31].

In most works involving tannin plants, aqueous organic solvents are the most adopted due to their easy handling, with methanol and acetone being the main ones due to the degree of yield, however, other solvents show promise in practice, such as ethanol [74]. The principle to understand the application of these solvents is the eluotropic scale which consists of using polarity as a means of extracting the active principles of plants, being necessary to know the class of compounds to be reflected and their water, in addition to the material available for use and the plant in question. There is still no definitive consensus on choosing the best tannin inheritance method, therefore screening and interaction studies between these compounds and organic solvents are extremely important [106].

When using organic solvents, it is also necessary to pay attention to the fact that their stability decreases with increasing temperature and exposure to sunlight. A shelf extract exposure between 2 and 5 hours, depending on the degree of storage, affected the efficacy, given the choice of acetone or methanol [14]. The proportion of plant material/solvent and the transmission time can also interfere with the amount to be extracted [106]. In general, the temperature, the solvent and its proportion in relation to the plant material act interdependently [51].

Maceration is one of the most used techniques, being in accordance with a physical training that uses thermodynamics such as temperature and applied force. The time for ingestion can vary from 30 to 40 minutes, however what will define is the time for overcoming the surface membrane of the plant giving access to its constituents and their degree of conductivity together with the type of solvent that can be used, being usually ethanol, methanol and water [15].

Water is employed to extract polar substances particularly when it has experienced a temperature corresponding to its boiling, where components containing carboxylic acid and hydroxyl



groups are extracted through hydrogen bonds, however due to the polarity of organic solvents are still the best choice [75]. Water as a solvent in pediatrics requires temperatures between 60° to 120° C when used together with methanol or ethanol [25]. The concentration of aqueous solvents seems to be directly related to the absorbance value since between the use of methanol and acetone, the higher the concentration, the greater the decrease in absorbance. If acetone is not used in the sample, there is a decrease in absorbance and time, which is why it is chosen recurrently [74].

In some cases, ingestion process accelerators can be used, taking vanillin and phenolic aldehyde as an example to increase precision as additives for quantification of the crude extract, that is, to provide greater precision in the calculation of polyphenols together with sodium sulfite in a process called sulfitation to increase the total material, making it more evident [21]. The addition of enzymes ends up accelerating the processes within the cell membrane, which makes the guarantee even more effective [25].

In addition to traditional laboratory methods, it is possible to use distillable ionic liquid ingestion for large-scale production of plant-derived tannins that are used for commercial leather tanning. The infrared method increases efficiency according to the wavelength of the heater and the distance between the source and the solvent material. There are also other techniques such as supercritical, ionic, liquid-assisted and pressurized hot microwaves [25].

## MEDICINAL PLANTS AND TANNINS IN WOUND HEALING

Among the plants that have a healing action with activity related to tannins, it is possible to highlight *Punica granatum*, which, based on the analysis of the bark by methanolic inheritance at 75% with the use of soxhlet, highlighted the increase in granulation tissue, mainly related to the isolated tannic of type A and B punicalagin, as well as gallic and ellagic acid [43] visited the wound area if applied in gel vehicle, corresponding to 55% [80] to 95% of the wound edge [82].

This potential is also studied for other solvents such as 70% ethanol in burn wounds [78] and for cuts, ethyl ether tested an absolute positive effect [91], its effect being similar to the role of ampicillin in combating infectious agents in the lesion [65], with collagen stimulation being the main means of promoting action [91]. The action and other tannic isolates are also highlighted with the use of methanolic extract, being punicalin and penecalagin with antioxidant activity as described in table 1 [83].

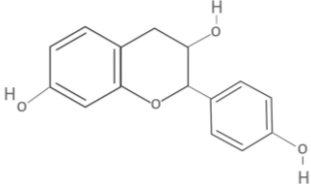
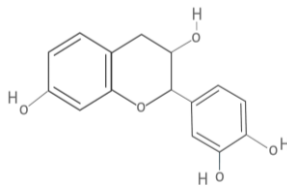
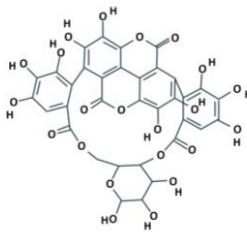
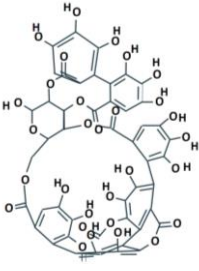
*Mimosa pudica* known as “sensitive plant” presents a healing effect as a methanolic extract after degreasing with total aqueous petroleum ether (extraction of the lipid recipe), being reported in addition to the ointment, evidencing the presence of alkaloids and mainly hydrolysable tannins, with a result on the fourth day and a peak on the eighth of the tissue, with the presence of hydroxyproline highlighted [54]. The use of this root based on the recommendation with methanol and chloroform solvent is related to the synthesis of growth factors [50]. Its effect on diabetic wounds is also reported [55].

Since the beginning of the 20th century, it has been possible to identify tannins from the phytochemistry of *Terminalia arjuna* [18], a factor responsible for increased migration and parenchyma trends from the hydroalcoholic recommendation with increased traction [20]. The use of ethanol solvent also demonstrating tannins has its effect related to the increase of hydroxyproline favoring the formation of type 1 collagen, mainly in the gel formulation [98]. It has in its aqueous extract action in a norepinephrine ring, mainly in the inflammatory phase and hypotensive effect [109] in addition to combating agents such as *Propionibacterium acnes* [112] and anti-inflammatory activity directly related to tannins [118] and induction of cancer cells [52].

The use of *Terminalia arjuna leaves* from the use of ethanol solvent demonstrates activity related to increased traction and collagen stimulation, helping in neovascularization [107, 66], and combating bacteria such as *Staphylococcus epidermidis*, *Staphylococcus subtilis* and *Staphylococcus aureus* [53], the presence of tannins [103] and the antioxidant activity promoted by it having already been demonstrated in phytochemistry, preventing the shortening of telomeres, a process responsible for the state of the skin causing aging [84].



**Table 1** . Main tannic isolates with healing action reported in the literature.

Structure	Name	Formula	Reference
	guibourtinidol	$C_{15}H_{14}O_4$	[95]
	Fisetinidol	$C_{15}H_{14}O_5$	
	Punicalin	$C_{34}H_{22}O_{22}$	[83]
	punicalagin	$C_{48}H_{28}O_{30}$	[43]

It is seen that the tannins have about 14 isolates related to healing activity divided into 4 groups, the carboxylics, gallotannins, ellagitannins and without specifications for containing isolated particularities, both easily dissociated in high pH anions, some of which are found in the methanolic extract of *Terminalia chebula* [60] with identification by HPLC [55].

The use of methanolic extract from the bark of *Lafoensia pacari* is due to the presence of saponins, steroids and mainly pyrogallol tannins, with its anti-inflammatory activity also being evidenced by the intensified COX 1 and reduction of oxidative stress [34]. The 70% hydroethanolic extract of the leaves also demonstrates macrophage-promoting action in lesions, as well as in ulcers and gastritis [90].

*Poincianella pluviosa* has already demonstrated an effect on tissue processing in the optimization of keratinocytes and fibroblasts by brute, with polyphenols being the most related to this activity [10]. Condensed tannins together with triterpenes collaborate in the proliferative cascade by stimulating chemical mediation, with the best result coming from methanol inheritance in the formation of carboxy cellulose polymers on an injured area [40].

The ethanolic extract of *Psidium guajava leaves* has a healing effect on gingival cells related to its tannins and flavonoids [33, 93]. It has already been applied in formulation and gel with positive results in diabetic wounds [48]. Another plant already studied for this principle is *Stryphnodendron barbatiman* in formulations of 2.5 and 5% in cream [28, 33]. The use of its extract by ethyl acetate favored vasoconstriction and coagulation of proteins related to tannins [44], having anti-inflammatory activity [92], being able to potentiate results from optimization [108] and applied in formulations for chronic deficiencies such as diabetes [5], as well as possible properties to try to be applied to the ethanolic extract of *Cnidocolus quercifolius* [37].

Plants such as *Bauhinia unguolata* show healing action with the use of its ethyl acetate extract where its tannic isolates such as Guiboutinialol and fisetinidol inhibit reactive oxygen species and cell migration from the beginning of proteins [95]. *Quercus infector* from its ethanolic extract of dried leaves showed antioxidant activity related to free radical scavenging and increased granulation and collagenization [110], as well as *Blechnum orientale* [92]. Types such as *Mimosa tenuiflora* with ethanolic extract and *Quercus persica* are also well explained [96,118]. The use of polyherbals tends to have positive effects if applied to harmful processes, an example being the use of leaves of *Psidium guajava* and *Mellaostoma malabatericum* from ethanolic therapy, where their tannins produced action on wounds [77, 74].

**Table 2.** *In vivo* studies using extracts with tannins for wound healing (cutaneous) using plant extracts and their respective inheritance methods.

plant species (Popular name)	part of the plant	Hospitalization/fraction/isolation processes	wound model	Tested groups	Formulation of cream	Performance	closing %	References
<b>Research involving the use of tannins in healing without association with comorbidities</b>								
<i>Blechnum orientale</i> Linn	sheets	Methanol	Excision in the dorsal region in a rodent	(-) creamy base (+) 10% povidone-iodine	1% and 2% extract cream respectively	6.5%	1% extract (95%) and 2% extract (100%) - 14 days	[62]
<i>Terminalia chebula</i> (Meleric Mirabolan)	immature fruit	Ethanol 95%,	The dorsal surface of the rodent	(-) Vaseline ointment 5 mg per wound (+) Erythromycin ointment 5 mg per wound	Extracts at a dosage of 5 mg + vaseline, per wound	without measurement	Significant difference to the control (P< 0.05) 100% before the 21st	[67]
<i>terminalia arjuna</i> (Haritaki or arjuna bark)	bark	Ethanol 50%	Incision in shaved skin and cutaneous muscles of rats	Untreated group; 100,300,10 mg/kg; 1.5 and 0.1%	Orally with 150 and 300 mg kg of extract day and another 10 mg/day. And they contain 1.5 and 0.1% processed	12%	Topical application of 0.1% tannins with 462 g pull 16 days of treatment	[98]
<i>terminalia arjuna</i>	bark	Ethanol 50%	6 cm incision	(-) No application (+)Betadine	Cream with addition of hydroalcoholic extract	Not mentioned	Fraction rich in tannins with traction of 719 g. 9th day of experiment	[18]

Domingues de Barros et. al. - Tannins: plant-derived polyphenols that enhanced skin healing

<i>phaseoloid input</i> (Saint Thomas)	bark	Ethanol 95%	back injury	(-) 5 mg vaseline ointment  (+) 5 mg Bactroban	Formulation: Vaseline + 5 mg of extract.	do not measure  .uproar	On the 14th day, the Test Wounds showed partial epithelialization without itching	[102]
<i>Salarbio Corp</i> (Cas 1401-55-4, HPLC ‡ 98%, China).	Specific tannic acids	Tannins 2g/mL stock solutions	Incision in the dorsal region	White group: No application, left separately and test group	0.25 mL of TA were used at different concentrations of 1.5, 1.0 and 0.5g/mL, respectively	not measured	Model group of 98.43%; comparing the mice TA-treated with YB-treated rats, group YB after day 7 and almost healed on day 15.	[22]
<i>Persian Quercus</i> (Black Oak)	bark	Methanol	Incision 2.0 cm long and 0.2 cm deep	Ucerin-based ointment and untreated group	The experimental group was treated by daily application of 5% methanolic extract ointment.	No percentage measured	94.41±0.26 26 days after starting the application.	[7]
<i>Bauhinia unguolata L</i> (Bovine leg).	stem wood	hexane (4 × 10 L) and ethanol (4 × 10 L)	Incision in the back region	Base Formulation	Topically treated with 200µL of 0.5% FABU gel once daily for 5 days	80%	Significant repair on the 14th day of treatment	[95]
<i>poincianella pluvirosa</i> (Sebipira)	bark	20L of EtOH-water (1:1 v/v)	<i>In vitro</i> cell culture	Positive control: cells treated with 5% FCS  And the untreated negative	Mitochondrial activity was assessed by the MTT test, the rate of myogenic cell prospects by incorporation of BrdU	Not mentioned	Significant reduction in the 10th day (no reduction by area %)	[10]



					Assay and release of lactate dehydrogenase			
<i>poincianella pluviosa</i> (Sebipira)	stem bark	Ethanol 50%	Incision in the back region	not described	Polymer film added over wound	Not mentioned	Significant difference from 10th to 14th (without %)	[38]
<i>Lafoensia pacari</i> (Foxglove)	sheets	Extracted with 50% acetone/water in an ultrasonic bath for 30 min at a drug:solvent ratio of 10% (w/v).	Incision in the dorsocervical region	Negative control: Distilled water Positive Control: Base cream for days	10% <i>L. pacari</i> extract in distilled water	Not mentioned	Significant difference from the 7th to 14th day of treatment	[17]
<i>Lafoensia pacari</i> (Foxglove)	sheets	Maceration in 70% hydroethanolic solution (1:10, w/v) for 7 days at 25°C to obtain the aqueous ethanolic extract	6 cm incision up to the fascia in the craniocaudal direction in the dorso-lumbar region	Positive Control: Doxorubicin Negative control: No application	Not mentioned	Not mentioned	Complete re-epithelialization of the wound in 22.0 ± 1.5 (p < 0.05) and 21.7 ± 1.6 (p < 0.01) days	[90]



Domingues de Barros et. al. - Tannins: plant-derived polyphenols that enhanced skin healing

<i>prudish mimosa</i> (Do not touch me)	sheets	Acetone + Water (7:3) by the cold maceration method. Petroleum ether is added to this filtrate.	back injury	Negative control: Plain ointment (e.g. beeswax, cetostearyl alcohol, etc.), Positive control: 5% povidone iodide	<i>Mimosa pudica</i> and ointment applied 5%	Not mentioned	On the 19th day reduction in length of 0.69 mm and width of 1.17.	[19]
<i>prudish mimosa</i> (Do not touch me)	source	Total aqueous extract was prepared by decoction method with distilled water in the ratio of 1:5	Excision on the back in a circular shape (approx. 500 mm <sup>2</sup> )	Simple ointment blood control	Ointment containing 1% and 2% (no formula description) total aqueous extract	14.42%	1% of the extract (88.69%) 2% of the extract (97.34%)	[54]
<i>Stryphnode ndron adstrigens</i> (Barbatimã o)	Not mentioned	Not mentioned	Ovariohysterectomy injuries	placebo ointment	Manipulated ointment based on barbatimã in the percentage of 2.5 and 10%	Not mentioned	In 15 days it was obtained: 2.5% (2.5%); 10% (1.7%)	[28]
<i>Rubia cordifolia</i> L. (Indian madder)	roots	Ethanol (95%)	back of mice	flat base	A 0.2%, 0.5% and 1% gel	9%	Reduction of 4.7 mm in 7 days from the 1st application	[47]



<i>Psidium guajava</i> Linn (Guava)	sheets	Acetone (70% v/v)	mouse coast	Negative control: control (white gel without drug. Positive control: 0.8% formalin aqueous solution	5% and 10% gels.	Not mentioned	Reduction in 5% Gel (57.57 mm) and 10% Gel (103.62 mm) in 12 Days.	[48]
<i>Psidium guajava</i> Linn (Guava)	leaves and bark	Ethanol and solvents of increasing polarity such as petroleum ether, chloroform, ethanol and aqueous to produce its production	rodent coast	Negative Control: Plain ointment (eg, beeswax, cetostearyl alcohol Positive Control: 5% Povidin iodine ointment	5% of the extract in the ointment	Not mentioned	Contraction of 94.81% in 16 days of treatment	[93]
<i>Psidium guajava</i> Linn (Guava)	sheets	70% ethanol	On the tongue with a 3 mm diameter circular scalpel.	not described	Two applied applications of the swab-tested drug at 12-hour intervals throughout the experiment	Not mentioned	Significant repair on the 3rd to 14th Day (No percentage)	[33]



<i>Mimosa tenuiflora</i> (Calumbi)	husks	By maceration with ethanol for 72 h at room temperature	Double-blind clinical trial, randomized and placebo-controlled	Treated and untreated groups	hydrogel	Not mentioned	92% reduction in 21 days of treatment	[96]
<i>Stryphnodendron adstringens</i> (Barbatimão)	Not mentioned	Uninformed	back of rodents	Negative control: 0.9% regulatory solution Positive control: Formulated ointment	Barbatimão 10%	Not mentioned	100% on the 14th day of treatment	[102]
<i>Pterolobium hexapetalum</i>	sheets	Organic solvents (500 mL) such as petroleum ether, ethyl acetate and methanol in increasing order of their polarity	Excision wound on the back	Negative control: Ointment without actives Positive control: Neomycin 5%	2.5% and 5% of the ointment	Not mentioned	100% reduction in 21 days of treatment	[103]
<i>Quercus infectoria</i>	sheets	95% Ethanol	On the backs of rodents there were Two incisions for vertebral	Not mentioned	In acute toxicity: increasing doses (1, 2, 4 and 8 g / kg body weight)	270 g	Epithelialization of 98, 58 on the 14th day of treatment	[110]



					In the incision: 400 and 800 mg/kg			
Research involving polyherbal in wound healing								
<i>malva sylvestris</i> <i>Solanum nigrum</i> <i>damask rose</i>	sheets petal oil	Sesame oil as a solvent	15 mm deep circular burn on back	Negative control: No medication  Positive control: 1% fadiazine silver sulfate (SS) cream	Aqueous extract of M. silvers and S. nigrum and 33% oil extract of R. damascena in a cream base including eucerin (25%), white vaseline (28%) and white beeswax (4%).	Not mentioned	54.8% better than the control on Day 14 of treatment	[30]

**Table 3 .** *In vivo* experimental research involving tannins in healing diabetic wounds.

plant species (Popular name)	part of the plant	Hospitalization/fraction/isolation processes	wound model	Tested groups	cream formulation	Performance	Wound Decrease	References
<i>butea gum</i>	gum	Boiling water and sated brine solution	dead space	Not mentioned	Powdered substance, which has been treated with ether	42%	Formation of granulation tissue on the 8th day, (Not mentioned %)	[58]



<i>Psidium guajava</i> Linn (Guava)	sheets	Extracted with acetone (70% v/v) by the cold maceration method, this fraction was evaporated and used for the study.	A single dose of 84 mg/kg of alloxane monohydrate dissolved in saline mouse back	Negative control: control (white gel without drug)  Positive control: 0.8% formalin aqueous solution	5% and 10% gels	Not mentioned	5% gel fraction (76.27 for 18.70 mm) and 10% gel fraction (110.29 for 6.67 mm)	[52]
Research involving polyherbal								
<i>Melastoma malabathricum</i> L. from <i>Psidium guajava</i> L.	sheets	oven at ± 50EC and 70% ethanol	dorsal surface of the foot	5 groups in a hyperglycemic state, then the mice were induced using a 10 g alloxan monohydrate injection	Mixture of leaf extracts	Not mentioned	40 to 29.6 mm <sup>2</sup> in 5 days	[77]

**Table 4 .** *In vivo* experimental research involving the use of tannins in healing associated with burns

plant species (Popular name)	part of the plant	Hospitalization /fraction/isolation processes	wound model	Tested groups	cream formulation	Performance	Wound Decrease	References
---------------------------------	-------------------	---	-------------	---------------	-------------------	-------------	----------------	------------



<i>punica granatum</i> (Pomegranate)	flower	Aqueous ethanol (70%)	Supine position on box with back up	Saline Solution and Base Cream	<p>Creams containing 5% And 10% extract</p> <p>It was mixed with liquid paraffin, stearyl alcohol, cetyl Alcohol and Span 80 to 70°</p>	26.8%.	Size of 1 cm <sup>2</sup> without 20° diameter	[85]
<i>prudish mimosa</i> (Do not touch me)	source	Chloroform and methanol	6 cm long straight paraspinal incisions	Group I, Untreated control; Group II, Simple Ointment	<p>The methanolic extract formulation was prepared as 2.5% (w/w) and 5% (w/w) hydrophobic base as a simple ointment</p> <p>The chloroform extract was made at 2.5% (w/w) and 5% (w/w) in a hydrophilic base such as carbopol (1%) containing methyl paraben (0.01%) and propylparaben (0.1%) .</p>	Not mentioned	50% reduction compared to the control group on the 10th day	[50]



## **MAIN CONTROL OF ACTION OF TANNINS IN WOUND HEALING**

### **ANTIOXIDANT ACTION**

Reactive oxygen species (ROS) are the main cause of damage to the surface of the skin and are present in the environment. These compounds are produced and acquired at all times, and it is up to the body to bring about a balance between oxidant and antioxidant agents [71]. The antioxidant activity of tannins is dependent on the structures of absorption, neutralization of radicals and peroxide compounds [11]. In view of this, they act by avoiding lipid peroxidation, balancing the creation and elimination of peroxides, thus not becoming an aggravating factor [2, 86]. This class of polyphenols works from three main pathways, which are the elimination of free radicals, the chelation and transcription of metals and the orientation of pro-oxidative enzymes [70].

The lipid peroxidation time is dependent on characteristics such as molecular weight, ring hydroxylation and antioxidant potential of the analyzed constituents. The mechanism of action occurs through the orientation of pro-oxidative enzymes that age in nitric oxide synthase, generating an effect on lipoxygenase (LOX), which then damages membrane lipids, with research into this effect contributing to the discovery of phlorotannins, which are a class tannins and which has been highlighted for its potential use as an antioxidant and anti-inflammatory agent. The chelation pathway of heavy metals occurs through the binding of cations of metals such as iron and copper, which are cofactors of antioxidant enzymes such as catalase and superoxide dismutase. The lipid peroxidation pathway occurs through the oxidative modification of low-density lipoproteins, the most common being LDL [3, 59, 70].

Tannins have a wide variety of types, which can often dictate their antioxidant effect depending on their structural organization, however there is a wide relationship with proanthocyanidins belonging to the group of condensed tannins that due to their complex structural and ecological diversity Physical chemistry bestows this potential in a more illuminating way. From different tests using different identification pathways against an effect reducer, either by the antioxidant capacity by trolox equivalence (TEAC), iron reduction (FRAP) and 2, 2-diphenyl-1-picrylhydrazyl-hydrate (DPPH), antioxidant potential is already seen [119].

### **ANTI-INFLAMMATORY ACTIVITY**

Tannins relieve the pain threshold due to inflammatory hyperalgesia, where there is no continuous stimulation of inflammation during healing, which causes heating and other cardinal signs of inflammation, mainly edema, which would generate pain due to the release of endogenous mediators such as bradykinin and serotonin. In addition to this process, there is an increase in cyclooxygenase in the release of arachidonic acid by the biosynthesis of prostaglandins of the neurogenic phase, that is, there is a local psychological effect in prolonging the intensity of inflammation and this is due to the transition beyond the prostaglandin 2 (PGE<sub>2</sub>) and enzymatic acceleration that are stimulated by the induction of carbon dioxide (CO<sub>2</sub>) from the spinal cord and cyclooxygenase (COX-2). In addition, its effect may contribute to thermal, mechanical and muscular hyperalgesia pathways due to its high bioactivity in chronic pain, inhibiting chemical mediators such as TNF, IL 1 and PGE and decreasing nitric oxide responsible for great swelling, intensity and increased itching throughout the inflammatory phase in its extension of origin [27, 39, 91, 23, 101, 81], which would explain its potential against toothaches [94].

### **MICROBIOLOGICAL EFFECT**

Faced with the high level of problems facing bacterial resistance to antibiotics in their indiscriminate use by the population, several alternatives have been studied as a possible treatment model, one of which is the use of tannins because they are of plant origin and have good distribution and low toxicity [29]. This action is related to several action pathways against gram positive and negative bacteria, the main ones being induced cell synthesis, combating the formation of biofilms,



enzyme induced and iron chelation where the o-dihydroxyphenyl groups are linked by ferric ions that unite at the molecular level [16].

The antibacterial effect of tannins is related to the surface components and their ability to non-covalently associate with proteins and other macromolecules which, if done successfully, causes bacterial susceptibility, this compound causes the lysis process and consequently the death of microorganisms which may delay healing by producing exudate [35]. Some analyzes have already been carried out on the class of bacteria that present this susceptibility, considering that species such as *Staphylococcus aureus*, *Staphylococcus luteus*, *Staphylococcus epidermidis*, *Proteus vulgaris*, *Escherichia coli*, *Salmonella typhi*, *Listeria innocua* and *Bacillus cereus* have also been shown to bacteriostatic action in these groups [61, 26, 11], also in the literature it is possible to find action in other less pathogenic types, such as *Propionibacterium acnes* [42] and having already experiments with formation of minimum inhibitory concentrations (MIC) higher than 1600 µg mL<sup>-1</sup> that are considered bactericidal [32].

Its action against fungal groups that can also disrupt tissue control is still little related, however, it is known that its mechanism of action depends on the destabilization and permeation of the cytoplasmic cell membrane, driven by extracellular membrane enzymes and direct actions on its metabolism, which consequently generates death to the infectious agent [11]. It is seen that the presence of carbohydrates in tannins reduces their antifungal efficiency [25].

In research carried out in groups of basidiomycetes, ascomycetes and mitosporas (deuteromycetes) it was seen that tannins function with their own inhibitory effect from these previously mentioned pathways. Within the growth of the so-called brown subgroups in relation to the white and soft types, this designation referring to the factor of decay and destruction of the plant support of fungal groups dispersed in the environment, to which these classes were identified for the first time, it is seen the decay of their survival with a fungicidal character with the addition of copper impregnation, although not many cause resistance in humans, being more present in the commercial sphere, they observe the quality of export in wood [5].

## PHYSICAL BARRIER

Tannins have as their main pathway in healing the formation of a layer on the surface of the epithelium that encourages the formation of collagen, elastin and components of the extracellular matrix that fight infectious agents, functioning as a mechanical barrier preventing physical particles (eg dust, pollen, etc) come into contact with the area that would be exposed [67]. This constipated layer of polysaccharide acts in the fight against free radicals and neoplasms by stimulating agents such as tissue factor (TF), which participates in an accompanying way in the cascade of coagulation and cytokine migration [46, 114].

It is the formation of this film that the healing phases are not negatively sustained by microbial agents that received exudate formation, mainly in the inflammatory and proliferative phase, with the action of chemotactic growth factors and overlapping of vascular connective tissue with re-epithelialization and vessel formation [56, 81]. Tannins thus end up increasing the number of cells continuously without affecting the migration of agents such as keratinocytes and essential proteins such as collagen and elastin during the last stages of epithelialization [89]. The use of tannic acid should still be boosted in the production of creams and cosmetics, as it aids in the stability of this formula with a high water content, with an emphasis on hydrogels increasing its crosslinking which even better seen in rheological analyzes increased its attraction and prospects cell according to the chosen property [66].

## CLINICAL USE IN COMORBIDITIES

In the population with chronic diseases, secondary interferences such as hormonal, behavioral and chemical interaction factors can generate immense difficulty in the duration of the healing process, mainly in the formation of ulcers due to dermal xerosis of the lower limbs in diabetics with



uncompensated hyperglycemia [1, 100]. For the treatment to work properly, it is necessary to understand the entire pathological process in question for adequate traditional use together with the practice of scientific knowledge about what is present there and how it can interact to generate some kind of benefit in the short term. An example of type 2 diabetes where the use of free radical chelating products decreases the amount of reactive oxygen species and increases the formation of capillaries, generating oxygenation and stimulation of fibroblasts, thus being a great alternative to this problem [67].

With regard to tannins, they can be applied to the skin from a vehicle, helping to maintain a favorable microenvironment, which is humid, allowing and accelerating controls. Tannins are closely linked in the regulation of enzymatic activities, which configures an action in the fight against several pathologies that can be from diabetes mellitus to the rarest, acting in a systemic way from its consumption and topically in wound healing, being also seen that its functionality is related to non-damage to the membrane and combating neoplasms [41, 61] .

Despite this high potential for use, it is worth noting that the tannins had a limited effect due to their tendency to interact with other so-called substances, their low chemical stability, rapid metabolism and low availability, requiring the development of means that preserve them for a longer time compared to the its clinical use that can last for days, either this topic or systemically as an example of using the encapsulation process [68].

## **THERAPEUTIC POTENTIAL**

The action of tannins in wound healing is evident, acting through multiple ways of action such as their antimicrobial action, as a physical barrier and stimulator of fibroblasts, neutrophils and macrophages, these of which interact and function at the same time in the cascade of processes of respectability. This efficiency is dependent on the minimum amount of these polyphenols in a given location or systemically with the formation of agents such as blood vessels by stimulating angiogenesis, which is one of the main precursors of tissue nutrition and inflammatory intensity [47, 30, 93, 28] .

It is evident that the tannins act by stimulating mainly the fibroblasts that continue to stimulate collagen and elastin, which are the main agents responsible for the reduction of the lesion. epidermis that has antibacterial activity [64, 17, 48, 101, 9, 7]. This pathway also stimulates keratinocytes, which are agents belonging to the dermal layer and have a pro-inflammatory action in stimulating cytokines [22].

Antioxidant activity is the main agent responsible for contributing to healing time, which is the main means of combating cells that may undergo the presentation process together with granulation agents [110]. It is clear to point out that tannins from these aforementioned routes have an enormous potential for clinical applicability, which is sometimes still unlikely in medical routine, due to the greater incentive for synthetic products [100, 95].

It is evident the contribution that this compound tends to bring to a population that often uses plants rich in tannins in food, being more evident in the preparation of teas. If tannins are applied, not only does it offer the convenience of being cheaper and more accessible to the population, but also for those who use it in healing, it is possible to observe the formation of crusts in a shorter time, absence of itching and better tissue organization, bringing elasticity and a better degree of of skin contraction [72].

## **CONCLUSION**

Tannins are constituents of plants that received protection against predators, being reported in traditional medicine as a healing agent and acting in all phases of tissue reconstitution, mainly in inflammation and remodeling. In view of this, the present literary overview demonstrates that tannins act in an anti-radical, anti-inflammatory way, in the fight against bacterial and fungal microorganisms, as well as generating a physical barrier, elucidating the importance of looking for better ways to stabilize



and deliver this compound as a therapeutic model, which can be done mainly through creams and gels increasing their permanence time under the injured skin.

### THANKS

To the coordination of higher level personal improvement - CAPES (Process 001);

### Declaration by Authors

**Ethical Approval:** Approved

**Acknowledgement:** None

**Source of Funding:** None

**Conflict of Interest:** The authors declare no conflict of interests.

### REFERENCES

- (1) Andrade, MG L et al. Evidence of changes in the healing process of burns in diabetic individuals: a summary review. **Rev Bras Queimaduras** . 2013; 12(1):42-8
- (2) Andrade, JMM et al. Identification of compounds from nonpolar fractions of *Blechnum* spp and a multitarget approach involving enzymatic modulation and oxidative stress. **Journal of Pharmacy and Pharmacology** , 69 (2017), pp. 89–98
- (3) Aziz et al. Inhibition of 15-lipoxygenase by *Blechnum orientale* leaves and their isolated flavonoid glycosides: in vitro and in silico studies. **HAYATI J Biosci** 355 Vol. 29 No. 3, May 2022
- (4) Aguiar, PS et al. Benefits of *Stryphnodendron adstringens* when associated with hydrogel in wound healing in diabetic rats. **Clinical Phytoscience** (2021) 7:22; doi: <https://doi.org/10.1186/s40816-021-00257-5>
- (5) Anttila, A.-K. and others (2013). Condensed tannins from conifers as antifungal agents in liquid culture. **Holzforschung**, 67(7). <https://doi.org/10.1515/hf-2012-0154>
- (6) Aragão-Neto, AC et al. Combined therapy with low power laser and chitosan policaju hydrogel for wound healing. **International Journal of Biological Macromolecules** , p. 268-272, 2017.
- (7) Akran, E. et al. Evaluation of the antibacterial and healing activity of *Quercus persica*. **Journal of Basic & Applied Sciences** , 2012, 8, 118-123
- (8) Baptistel AC Coutinho, JMCP Neto-Lins, EMF Monteiro, JM Medicinal plants used in the Santo Antônio Community, Currais, southern Piauí: an ethnobotanical approach. **Rev. Bras. Pl. Med** ., Campinas, v.16, n.2, p.406-425, 2014.
- (9) Bueno, FG et al. Hydrolyzable tannins from the hydroalcoholic extract of the stem bark of *Poincianella pluviosa* and its healing properties: phytochemical investigations and influence on in vitro cellular physiology of human keratinocytes and dermal fibroblasts. **Phytotherapy** 99 (2014) 252–260.
- (10) Bueno, FG et al. Skin Wound Healing Enhanced In Vivo by Standardized Crude Extract of *Poincianella pluviosa*. **PLOS ONE** | <https://doi.org/10.1371/journal.pone.0149223> March 3, 2016
- (11) Cano, A. et al. Use of tannins to improve the functional properties of protein-based films. **Food Hydrocolloids** 100 (2020) 105443.
- (12) Castro, MR Figueiredo, FF Traditional knowledge, biodiversity, integrative and complementary practices: the use of medicinal plants in the SUS. **Hygeia** 15 (31): 56 - 70, March/2019.



- (13) Cortez, DN et al. Costs of treating skin lesions in Primary Health Care. **ESTIMATE, Braz. J. Enterostomal Ther.** , São Paulo, v.17, and 2419, 2019.
- (14) Cork, J. Krockenberger , AK Methods and pitfalls of transmission of condensed tannins and other plant phenolics: research insights in eucalyptus leaves. **J Chem Eco** . 1991 January;17(1):123-34. <https://doi.org/10.1007/BF00994426>
- (15) Cuong, DX et al. Tannins: traction for plants. **Tannins: Structural Properties, Biological Properties and Current Knowledge**. p: 57-77, 2020
- (16) Cruz, EH et al. Poly(vinyl alcohol)/cationic tannin blend films with antioxidant and antimicrobial activities. **Materials Science and Engineering C** 107 (2020) 110357
- (17) Chaibud, BA et al. Pharmacognosy Investigation of the healing activity of the extract of the leaves of *Lafoensia pacari* (Lythraceae) cultivated in the state of Goiás, Brazil. **Pharmacognosy** , Rodriguésia 71 (2020). <https://doi.org/10.1590/2175-7860202071058>
- (18) Chaudhari, M. Mengi, S. Evaluation of *Terminalia arjuna* Phytoconstituents for Wound Healing Activity in Rats. **Phytother** . Res. 20, 799–805 (2006)
- (19) Chamakuri, SR et al. Different Fractions of *Mimosa pudica* by Healing Activity. **Journal of Chemical and Pharmaceutical Research** , 2019, 11(3): 14-21.
- (20) Chopra, RN Ghosh, S. *Terminalia arjuna* . **The Indian Medical Journal** , p. 70-73, (February) 1929.
- (21) Chavan, U., Shahidi, F., & Naczk, M. Extraction of condensed tannins from beach pea (*Lathyrus maritimus* L.) as affected by different solvents. **Food Chemistry** , 75(4), 509-512, (2001), [https://doi.org/10.1016/s0308-8146\(01\)00234-5](https://doi.org/10.1016/s0308-8146(01)00234-5)
- (22) Chen, Y. et al., Tannic Acid Accelerates Cutaneous Wound Healing in Rats Via Activation of the ERK 1/2 Signaling Pathways. **Advances in wound care** , *wound.2018.0853*-. <https://doi.org/10.1089/wound.2018.0853>
- (23) Chopade, AR et al. Pharmacological Aspects of *Phyllanthus fraternus* Standardized Extract (Rich in Lignans and Tannins) as a Pain Modulator. **The Open Pain Journal** , 2020, Volume 13.
- (24) Dias, RAL et al. Drying and Total Tannin Extraction from Spearmint (*Mentha x Vilosa* Hudson). **Rev. agarian**. v.4, n.12, p.123-133, 2011.
- (25) Das, AK et al. Review on tannins: extraction processes, applications and possibilities. **South African Journal of Botany** 135 (2020) 5870.
- (26) Doss, A. et al. Antibacterial activity of tannins from *Solanum trilobatum* Linn leaves . **Indian Journal of Science and Technology** . Vol.2, pages 41-43, n° 2 (February 2009), ISSN: 0974-6846.
- (27) Ebaid, R., Ahmed, OM Mahmoud, AM Ahmed, R. Limiting prolonged inflammation during the proliferation and remodeling phases of wound healing in streptozotocin-induced diabetic rats supplemented with undenatured camel whey protein. **Rev. BMC Immunology** , 2013.
- (28) Fagundes, SK et al. Efficacy of barbatimão ointment (*Stryphnodendron barbatiman*) in the healing of iatrogenic scars in cats. **Archives of Veterinary Sciences and Zoology at UNIPAR** , Umuarama, v. 23, no. 2, count 2310, 2020.
- (29) Farha, AK Tannins as an alternative to antibiotics. **Food Bioscience** 38 (2020) 100751
- (30) Fahimi, S. et al. Wound healing activity of a traditionally used herbal product in a rat burn model. **Iran Red Crescent Med J**. 2015 September; 17(9): e19960
- (31) Fawole, OA et al. Anti-inflammatory, anticholinesterase, antioxidant and phytochemical properties of medicinal plants used for pain-related diseases in South Africa. **Journal of Ethnopharmacology** 127 (2010) 235–241.



- (32) Fernandes, AFC et al. Antiproliferative, antileishmanial and antimicrobial studies in *Cnidocolus quercifolius* Pohl (Euphorbiaceae) Antiproliferative, antileishmanial and antimicrobial studies in *Cnidocolus quercifolius* Pohl (Euphorbiaceae). **NATURAL PRODUCTS RESEARCH**, 2020 Informa UK Limited, trading as Taylor & Francis Group
- (33) Fernandes, KPS Healing and cytotoxic effects of *Psidium guajava* (Myrtaceae) leaf extracts. **Braz J Oral Sci**. 9(4):449-454
- (34) Filho, PTetal. Evaluation of the antiulcer activity and mechanism of fractionation of methanol extracts from the stem bark of *Lafoensia pacari* A. St.-Hil. (Lytraceae) in experimental animals. **Journal of Ethnopharmacology** 144 (2012) 497–505
- (35) Figueroa-Espinoza, Maria-Cruz & Ratisbonne-Zafimahova, Andrea & Maldonado Alvarado, Pedro & Dubreucq, Eric & Poncet-Legrand, Céline. (2015). Grape seed and apple tannins: emulsifying and antioxidant properties.
- (36) Fonseca P. Librandi, APL Evaluation of the chemical, physical and phytochemical characteristics of different tinctures of barbatimão (*Stryphnodendron barbatiman*). **Brazilian Journal of Pharmaceutical Sciences**, v. 44, No. 2, 2008.
- (37) Gomes, TB Bandeira, FPSF Use and diversity of medicinal plants in 23,533 ± 0.01a quilombola community in Raso da Catarina, Bahia. **Acta Botanica Brasilica** 26(4): 796-809. 2012.
- (38) Guidi, ACS Poincianella pluviosa bark extract incorporated into polymeric film: Evaluation of wound healing and anti-staphylococcal activities. **Injury** 51 (2020) 840–849
- (39) Gomes, LCS; Carmo, KF Effects of high power ultrasound in the treatment of localized lipodystrophy: Case report. **Health and science electronic magazine**, v. 5, no. 2, pg. 25-33, 2015.
- (40) Gomes, LMA et al. Antinociceptive activity of the ethanolic extract of the bark and leaves of *Cnidocolus quercifolius* (Euphorbiaceae) in mice. **Journal of Young Pharmacists** Vol 6 • Issue 2 • Apr-Jun 2014
- (41) Gupta A. et al. Screening of the flavonoid-rich fraction of three Indian medicinal plants used for the treatment of liver diseases. **Rev. Brasileira de Framacognosia**, p. 485-490, 2015.
- (42) Gurnig, K. et al. Determination of Total Tannins and Antibacterial Activities Ethanol Extraction Seri Leaves (*Muntingia calabura* L.). **Journal of Physics: Conference Series**, 1811 (2021) 012121, IOP Publishing, doi: 10.1088/1742-6596/1811/1/012121
- (43) Hayouni, EA et al. Ointment based on hydroalcoholic extract of *Punica granatum* L. bark with greater in vivo healing potential in dermal wounds. **Phytomedicine** 18 (2011) 976– 984
- (44) Hernandez, L. Evaluation of healing of *Stryphnodendron adstringens* ointment (barbatimão) in rat skin. **Brazilian Journal of Pharmaceutical Sciences**, 2010.
- (45) Hoyos-Martínez, PL et al. Tannin extraction: Key point for its valorization and cleaner production. **Journal of Cleaner Production** 206 (2019) 1138e1155
- (46) Jesus, NZT et al. Tannins, Peptic Ulcers and Related Mechanisms. **Int. J. Mol. science**. V.13, P. 3203-3228, 2012
- (47) Karodi, R. et al. Evaluation of the healing activity of a crude extract of *Rubia cordifolia* L. (Indian redhead) in mice. **International Journal of Applied Research in Natural Products** Vol. 2(2), pp. June 12-18, 2009 Available online <http://www.healthy-synergies.com> ©2009 Healthy Synergies Publications.
- (48) KumarI, SJ et al. Formulation and evaluation of herbal gel from the tannin-enriched fraction of *Psidium guajava* Linn. leaves for healing diabetic wounds. **International Journal of Green Pharmacy** • July-Sep 2018 (Suppl) • 12 (3) | S490

- (49) Kumar, RS et al. Evaluation of Healing Activity of Diabetic Incisional Wounds of *Mimosa pudica* L. Leaf Ethanol Extract in Rats. *International Journal of Pharmacognosy and Phytochemical Research* 2017; 9(8); 1143-1147
- (50) Paul. J. et al. Evaluation of wound healing of chloroform and methanolic extract of *mimosa pudica* roots in rats. *Int J Biol Med Res* . 2010; 1(4): 223-227
- (51) Ping, L. et al. Extraction of condensed tannins from grape pomace: Characterization and use as wood adhesives for wood particleboards. *Crops and Industrial Products* , Volume 34, Issue 1 , July 2011, Pages 907-914.
- (52) Kumari, SJ Formulation and evaluation of herbal gel from the tannin-enriched fraction of *Psidium guajava* Linn. leaves for healing diabetic wounds. *International Journal of Green Pharmacy* • July-Sep 2018 (Supl) • 12 (3) | S490
- (53) Kannan, P. et al. Antibacterial activity of *Terminalia chebula* fruit extract. *African Journal of Microbiology Research* Vol. 3 (4) pp. 180-184 April 2009
- (54) Kokane, DD et al. Evaluation of the healing activity of *Mimosa pudica* root. *Journal of Ethnopharmacology* 124 (2009) 311–315.
- (55) Kumar, KJ et al. Effect of geographic variation on tannic acid, gallic acid, chebulinic acid and ethyl gallate contents in *Terminalia Chebula* fruits. *NPAIJ*, 2(3-4), 2006 [100-104].
- (56) Kuo, PL, and others. Casuarinin from the *terminalia arjuna* bar induces apoptosis in human breast adenocarcinoma cell cycle arrest in MCF-7 cells. *Plant Med* 2005; 71: 237-243
- (57) Kundu, A. et al. Wound healing activity of ethanol root extract and polyphenolic-rich fraction of *Potentilla fulgens*. *Taylor & Francis Group* , p. 1-12, 2015.
- (58) Kuppan, D. et al., Wound healing potential of tannin in dead space wounds in diabetic rats. *World J Pharm Sci* 2021; 9(8): 110-113.
- (59) Koleckar, V. et al. Condensed and hydrolyzable tannins as antioxidants influencing health. *Mini-Reviews in Medicinal Chemistry* , 2008, 8, 436-447.
- (60) Juang, L, J. et al. Determination of hydrolyzable tannins in the fruit of *Terminalia chebula* Retz. by high performance liquid chromatography and capillary electrophoresis. *J. Sep. Sci* . 2004, 27, 718-724.
- (61) Lai, HY et al. *Blechnum Orientale* Linn - a fern with potential as an antioxidant, anticancer and antibacterial agent. *Complementary and Alternative Medicine* 2010, 10:15 am
- (62) Lai, HY et al. Dermal healing potential in *Blechnum orientale* Linn. *BMC Complementary and Alternative Medicine* 2011, 11:62
- (63) Lai, JCY et al. Treatment for diabetic ulcers using a hydrogel formulation optimized with fern tannin with antibacterial and antioxidant properties. *Journal of Ethnopharmacology* 189 (2016) 277–289
- (64) Lai, HY et al. Isolation and characterization of a proanthocyanidin with antioxidant, antibacterial and anticancer properties from Fern *Blechnum orientale*. *Revista Farmacognosia* , January-March 2017, Vol 13, Issue 49
- (65) Lukiswanto, BS et al. Evaluation of the wound healing potential of whole pomegranate (*Punica granatum*) fruit extract on skin burns in rats (*Rattus norvegicus*). *J. Adv. Veterinarian. Animal Res.*, 6(2): 202–207, June 2019.
- (66) Lee, HY et al. Improvement of biostability and mechanical properties of hyaluronic acid hydrogels by tannic acid treatment. *Carbohydrate Polymers* 186 (2018) 290–298.
- (67) Li, K. et al. Tannin extracts from immature fruits of *Terminalia chebula* Fructus Retz. promote healing of skin wounds in mice. *BMC Complementary and Alternative Medicine* , p. 1-9, 2011.
- 



- (68) Liang, X. et al. Zein-pectin nanoparticles fortified with tannic acid: stability, properties, antioxidant activity and in vitro digestion. **Food Research International** 145 (2021) 110425
- (69) Lu, B. et al. Skin wound healing with a chitosan-gelatin sponge loaded with tannins and platelet-rich plasma, **International Journal of Biological Macromolecules** , p. 1-10, 2015.
- (70) Macáková, K. et al. Tannins and their influence on health. **Recent Advances in Medicinal Chemistry** , vol. 1, 2014, 159-208.
- (71) Machado, PA et al. Molecular mechanisms of antioxidant action of resveratrol intrinsic intracellular pathways. **Biosfera Encyclopedia** , Knowing Scientific Center - Goiânia, v.13 n.23; pg. 750, 2016.
- (72) Madhura, MR Mengi, SA Comparative effect of oral administration and topical application of alcoholic extract of Terminalia arjuna bark in incision and excision wounds in rats. **Phytotherapy** 74 (2003) 553–558
- (73) Medicare and Medicaid Services (USA). Available from: <<https://www.cms.gov/search/cms?keys=healing>> Accessed on: March 14, 2022.
- (74) Makkar, HPS Becker, K. vanillin-hc1 method for condensed tannins: effect of organic solvents used for tannin extraction. **Journal of Chemical Ecology** , vol. 19, No. 4, 1993
- (75) Markom, M. et al. Extraction of hydrolyzable tannins from Phyllanthus niruri Linn.: Effects of solvents and extraction methods. **Separation and Purification Technology** 52 (2007) 487–496
- (76) Mekonnen A. et al. In vivo wound healing activity and phytochemical screening of crude extract and various leaf fractions of Kalanchoe petitiiana A. rich (Crasulaceae) from a mouse. **Journal of Ethnopharmacology** , pg. 638-646, 2013.
- (77) Maigoda, TC Wound Healing and Blood Sugar Effect of Psidium guajava L. Leaves and Melastoma malabathricum L. Leaves in Rats with Diabetic Foot Ulcer. **Journal of Applied Sciences** , 19(4); 287-294, 2019
- (78) Ma, K. et al. Evaluation of the healing effect of Punica granatum L Peel Extract on deep second-degree burns in rats. **Trop J Pharm Res** , January 2015; 14(1): 73
- (79) Mukherjee, PK Evaluation of the wound healing activity of some herbal formulations. **Fitoter. res** . 17, 265–268 (2003)
- (80) Murthy, KN C et al. Study of the healing activity of Punica granatum peeling. **Journal of Medicinal Foods** VOL. 7, No. 2 | 2004.
- (81) Moreski, DAB Leite-Melo, EVS Bueno, FG Healing action of medicinal plants: a review study. **Arch. Science Health UNIPAR** , Umuarama, v. 22, no. 1, pg. 63-69, Jan./Apr. 2018.
- (82) Nayak. SB et al. Wound healing activity of the bark of Punica granatum fruit. **Journal of Medicinal Foods** , VOL. 16, No. 9 | 2013
- (83) Nema, N. et al. Topical in vivo wound healing activity of Punica Granatum bark extract in rats. **AJPCT** , 1[2] [2013],195-200.
- (84) Na, M. et al. Cytoprotective effect on oxidative stress and inhibitory effect on cellular aging of Terminalia chebula fruit. **Fitoter. Res.** 18, 737–741 (2004)
- (85) Nasiri, E. et al. The effects of Punica granatum flower extract on burn-induced skin lesions in rats. **Hindawi Publishing Corporation Advances in Pharmacological Sciences** Volume 2017, Article ID 3059745, 8 pages <http://dx.doi.org/10.1155/2017/3059745>
- (86) Nogueira, AJL et al. Tannins a review. **Rev. Integrated Topics of Botany**, Ed. Athena, p. 32-44, chap. 4, 2021.
- (87) Olczyk, Mencner P., Komosinska-Vassev L., K. The role of extracellular matrix components in cutaneous wound healing. **BioMed Research International** , V. 2014, p. 1-8, 2014



- (88) Passaretti, T. et al. Effective use of barbatimão (*Stryphnodendron barbatiman*) in the wound healing process: a literature review. **ABCS Health Science**, v. 41, 2016.
- (89) Pellenz, NL et al. Healing activity of *Stryphnodendron adstringens* (Mart.), a Brazilian species rich in tannins: literature review and case series. **Wound medicine** , v. 26, 2019.
- (90) Pereira, LOM et al. Lafoensia pacari A. St.-Hil.: Healing activity and mechanism of action of standardized hydroethanolic leaf extract. **Journal of Ethnopharmacology** 219 (2018) 337–350.
- (91) Pirbalout, AG et al. The wound healing activity of *Punica granatum* and *Achillea Kellalensis* flower extracts in Wistar rats. **Acta Poloniae Pharmaceutica – Drug Research** , vol. 67 No. 1 pp. 107-110, 2010
- (92) Pinto, SCG et al. *Stryphnodendron adstringens*: Unraveling wound healing in streptozotocin-induced diabetic rats. **Plant Med** 2015; 81: 1090–1096
- (93) Rao, CS Comparative Study of the Tannin Fraction of *Psidium guajava* Linn. Leaves and Bark for Healing Activity, **JPRPC | Volume 3 | Edition 4 | December 2015**.
- (94) Ramakrishnan, K. and Krishnan, MRVTannin – classification, analysis and applications. **Ancient science of life** , 13 (3-4), 232, 1994.
- (95) Rodrigues, RO et al. Antioxidant, anti-inflammatory and healing potential of the ethyl acetate fraction of *Bauhinia unguolata* L. (Fabaceae) in an in vitro and in vivo wound model. **Molecular Biology Reports** (2020) 47:2845–2859
- (96) Rivera-Arce, E. et al. Therapeutic efficacy of an extract of *Mimosa tenuiflora* cortex in the treatment of venous leg ulceration. **Journal of Ethnopharmacology** 109 (2007) 523–528  
Kokane, DD Evaluation of the wound healing activity of *Mimosa pudica* root. **Journal of Ethnopharmacology** 124 (2009) 311–315.
- (97) Raja F. Júnior, JPP Preliminary phytochemical analysis and GC-MS of methanolic extract of *Blechnum orientale* L. collected in Kothiyar, Kanyakumari district, Tamil Nadu, India. **Journal of Drug Delivery & Therapeutics**. 2019; 9(4-A):587-590
- (98) Rane, MM Mengi, SA Comparative effect of oral administration and topical application of alcoholic extract of *Terminalia arjuna* bark in incision and excision wounds in rats. **Phytotherapy** 74 (2003) 553–558
- (99) Rente, SCC; Mejia, DPM Application of 3MHz ultrasound in the treatment of gynoid lipodystrophy. **Articles BIO CURSOS**, Articles on dermatofunctional physiotherapy, 2015. P.121-132.
- (100) Rodrigues, D, F. et al. Barbatimão Bark Extract, *Stryphnodendron Adstringens* (Martius) Coville, In Wound Healing In Animals. **Biosphere Encyclopedia** , Knowing Scientific Center - Goiânia, v.9, N.16; pg. 2011584 3, 2013.
- (101) Rodriguez, JAM et al. Evaluation of granulation capacity in surgical wounds with condensed tannins in tio2 matrices. **Herb tea. Res. Simple Society Proc** . Vol. 1479 © 2012 Materials Research Society <https://doi.org/10.1557/opl.2012.1599>
- (102) Santos, AT Júnior, JM Cunha, GN Second intention healing of wounds in Wistar rats using *Stryphnodendron adstringens*. **Animal Science** , v.29, n.1, p.15-29, 2019.
- (103) Sathyanarayanan, S. et al. Chemical profiling of *Pterolobium hexapetalum* leaves by HPLC analysis and their productive wound healing activities in rats. **Biomedicine and Pharmacotherapy** , Volume 95, November 2017, pages 287-297
- (104) Sieniawska, E., Baj, T. (2017). Tannins. *Pharmacognosy*, 199–232. <https://doi.org/10.1016/b978-0-12-802104-0.00010-x>

- (105) Silva, LL et al. Importance of the use of medicinal plants in the processes of xerosis, fissures and healing in diabetes mellitus. **Rev. Bras. Pl. Med.** , Campinas, v.17, n.4, suppl. I, p.827-835, 2015.
- (101) Souza, SMC et al. Anti-inflammatory and anti-ulcer properties of Allemão Myracrodruon urundeuva (Anacardiaceae) tannins in rodents. **wiley interScience** , pg. 220-225. 2007.
- (102) Su, X. et al. Healing effect of total tannins from Entada phaseoloides (L.) Merr. in mouse. **Elsevier** , 2016.
- (103) Sharma, Kartik; Kumar, Vikas; Kaur, Jaspreet; Tanwar, Beenu; Goyal, Ankit; Sharma, Rakesh; Gat, Yogesh; Kumar, Ashwani (2019). *Health effects, sources, utilization and safety of tannins: a critical review*. **Toxin Reviews**, (), 1–13. <https://doi.org/10.1080/15569543.2019.1662813>
- (104) Shukla, V. Bhatena, Z. Broad-spectrum antiquorum detection activity of tannin-rich crude extracts of Indian medicinal plants. **Hindawi Publishing Corporation Scientific** , 2016.
- (105) Sharma, P. et al. Antiulcerogenic activity of Terminalia chebula fruit on experimentally induced ulcer in rats. **Pharmaceutical Biology** , 49:3, 262-268, 2011, DOI: <https://doi.org/10.3109/13880209.2010.503709>
- (106) Shad, MN et al. (2012). Optimization of tannin extraction efficiency from Cichorium intybus L.: application of response surface methodology. **J. Med. Plant Res.** 6. 4467-4474.
- (107) Saguna, L. et al. Influence of Terminalia chebula on the healing of dermal wounds in rats. **Fitoter. Res.** 16, 227–231 (2002)
- (108) Souza, JN et al. Optimization of ultrasound-assisted extraction of polyphenols, tannins and epigallocatechin gallate from bark extracts of Stryphnodendron adstringens (Mart.) Coville. **Pharmacognosy Magazine** | April-June 2014 | Volume 10 | Issue 38 (Supplement 2).
- (109) Takahashi, S. et al. Hypotensive effect in rats of hydrophilic Terminalia arjuna extract containing tannin-related compounds. **PHYTOTHERAPY RESEARCH**, VOL. 11, 424–427 (1997)
- (110) Umachigi, SP et al. Studies on the healing properties of Quercus infectoria. **Tropical Journal of Pharmaceutical Research** , March 2008; 7(1): 913-919
- (111) Vannuchi, H. et al. Role of Nutrients in Lipid Peroxidation and Antioxidant Defense System. **Medicine, Ribeirão Preto, Symposium: CLINICAL NUTRITION**, 31: 31-44, Jan./Mar. 1998
- (112) Vijayalakshmi, A. et al. Development and Evaluation of Antiacne Products from Terminalia arjuna Bark. **Int. J. PharmTech Res.** 2011.3(1).
- (113) Vizzotto, M. Krolow, AC Weber, GEB Secondary Metabolites Found in Plants and their Importance. **Embrapa- Brazilian Agricultural Research Corporation**, p. 6-16, Pelotas-RS, 2010.
- (114) Wolfe, RM Terril, TH Muir. JP Drying method and pattern source affect condensed tannin (CT) concentrations in perennial herbaceous legumes using simplified butanol-HCl CT analysis. **J. Sci Food Agric**, p. 1060–1067, 2008.
- (115) Yang B. Liu. P. Composition and biological activities of hydrolysable tannins from Phyllanthus emblica fruits. **J. Agricultural and food chemistry**, p. 529-541, 2014.
- (116) Yi Sun, Z. et al. A biocompatible bacterial cellulose/tannic acid compound with antibacterial and anti-biofilm activities for biomedical applications. **Materials Science and Engineering C** 106 (2020) 110249
- (117) Zeni, ALB Use of medicinal plants as home remedies in Primary Care in Blumenau, Santa Catarina, **Brazil, Ciência & Saúde Coletiva** , 22(8):2703-2712, 2017.
- (118) Zibanejad, S. et al. Healing effect of Quercus persica and Lawsonia inermis ointment on episiotomy wounds in primiparous women. **Res Med Sci** 2020;25:11
- 



(119) Zhou, Ch. et al. Structural diversity and antioxidant activity of fractionated condensed tannins from mangosteen pericarp. **Food Chemistry** 129 (2011) 1710–1720

**How to cite this article:**

Domingues de Barros, M., Xavier da Cunha, R., Saturnino de Oliveira, J. R., Sant'Anna da Silva, A. P., Gomes Bezerra, L. F., & de Menezes Lima, V. L. (2025). *Tannins: Plant-derived polyphenols that enhanced skin healing*. *International Journal of Digital Research*, E-ISSN: 3033-179X, 1(3), 82-109. <https://doi.org/10.63711/ijdr.net20250308>

\*\*\*\*\*



# Geographical Studies of Urbanization Processes and Their Spatial Organization in Bulgaria

Evelina Filatova<sup>1</sup>, Emilia Patarchanova<sup>2</sup>,

<sup>1</sup>PhD Student <sup>2</sup>Associate Professor

<sup>1,2</sup>Department of Geography, Ecology and Environmental Protection,  
Faculty of Mathematics and Natural Sciences, South-West University "Neofit Rilski", Blagoevgrad, Bulgaria.

<sup>1</sup>ORCID ID: 0009-0000-3356-9904 <sup>2</sup>ORCID ID: 0000-0002-1806-557X

Corresponding Author: Evelina Filatova [filatova.e@swu.bg](mailto:filatova.e@swu.bg) :

<https://doi.org/10.63711/ijdr.net20250309>

## ABSTRACT

Cities have always been drivers of culture and social progress. They are centers of socio-economic life, concentrating not only population, but also infrastructure, services, and others on their territory. Urban change is most often characterized by two main units of measurement: the degree of urbanization and the rate of growth of the urban population. Intensive urbanization in conditions of rapid population growth and its activity is a basic prerequisite for the need to create scientifically based concepts for the city and settlement formations. The development of settlements is an essential part of the development of society. Historical and geographical knowledge is necessary to clarify the genesis of settlements and understand modern settlement processes. From their formation as a geographical feature with an increasing concentration of functions and population on a limited territory to their current state of a complex and dynamic social organism, the development of cities gives rise to significant research interest. The settlement type of the city is relatively young, if compared to villages. The city is the result of the division of labor, the differentiation and concentration of non-agricultural activities. The emergence and development of certain cities must be linked to their place and contribution to public life during different periods. The growing industrialization since the middle of the last century has led to strong urbanization, which poses many challenges to cities, both in Europe and Bulgaria, and around the world. The growth of cities leads to serious demographic and economic changes, which modern cities have difficulty coping with. Therefore, they need research for the purpose of planning and good management in the name of citizens and business.

**Keywords:** *City development, Urbanization, Urban population, Spatial organization*

Copyright © 2026 The Author(s). This article is licensed under CC BY 4.0.



## INTRODUCTION

The development of human civilization has always been closely connected with the development of cities. Although the relative share of the population living in cities at the global and regional level has changed over time, the importance and functions of cities, their role in social life, have always dominated over rural settlements. Cities have been at the focus of changes, often their carriers or the

“field” for their creation and establishment (Shopov, K. 1993). That is why the scientific and research interests of specialists from various fields of knowledge have focused on them – from archaeologists who uncovered the most ancient settlements of the “river civilizations” (Mechnikov, 1898) to contemporary researchers of urbanized territories and creators of models for sustainable urban development. Among all of them, a worthy place is occupied by geographer researchers studying the influence of the environment on urban development (Stoyan Dinev, Hristo Ganev, Rumen Penin).

The emergence of cities in the past, their development over the centuries, and their contribution to social life during different periods should be associated with the geographical characteristics of the location and the significant changes in social life. The favorable geographical position of territories with water resources, fertile soils, and climatic conditions without significant fluctuations in temperature regimes were preferred in antiquity when establishing cities. During the Middle Ages, a favorable geographical position for the creation of cities was associated with territories possessing natural protection from several sides against attacks and wars, as well as territories with a crossroads geographical location.

The era of the Great Geographical Discoveries (GGD) defined coastal territories as places for the establishment of urban settlements. Their role in the development of trade between the Old and the New World and in the utilization of the resources of territories that were their natural hinterland was of key importance. They served as a kind of springboard toward the interior of the newly discovered territories. The industrialization carried out at the end of the 19th and the beginning of the 20th century led to accelerated urbanization, which established cities as leading settlements, assigned them new functions, and placed them before new challenges, both in Europe and around the world. The expansion of cities resulted in serious demographic and economic changes, which modern cities find difficult to cope with. (Garvanov, I., Slavova, S., Marinkov, Z., & Momchilov, G.)

Bulgaria, as part of European civilization, is also a territory where these processes are manifested. In its development, they are influenced both by global trends and by local, specific factors related to the national space and the region.

## LITERATURE REVIEW

The development of cities and urban space has always been connected with the understanding of the role of the geographical environment as a fundamental factor for their emergence and development. In scientific literature, this approach is known as geographical determinism. According to it, natural conditions largely determine social and spatial processes (H. Ernste, C. Philo, 102–110). At the beginning of the 20th century, Ellsworth Huntington and Ellen Semple developed the thesis that climate, relief, and resources directly influence the character of civilizations and cities.

In Bulgarian geographical science, the issues concerning the relationship between the natural environment and urban development have been discussed since Prof. Ivan Batakliiev and Prof. Georgi Bonchev, who analyzed the location and spatial functions of settlements depending on natural and geographical conditions. During the second half of the 20th century, Stoyan Dinev and Hristo Ganev deepened these studies, emphasizing the territorial organization and regional structure of the urban network in Bulgaria.

Contemporary Bulgarian authors such as Rumen Penin (2006), Petar Slaveykov (2008), Borislav Georgiev (2015), and Emilia Toncheva (2020), Patarchanova and Petrov (2021), expand the understanding of geographical determinism by including socio-economic, ethno-political, and cultural factors in their analyses. They point out that, despite the historical dependence of cities on the natural environment, in the contemporary stage of urbanization there is an increasing role of technological, political, and social processes in shaping urban space.

In the international context, the concept of geographical determinism has undergone an evolution—from classical physical determinism to the geographical possibilist approach (P. Vidal de la Blache, 1911), according to which nature provides opportunities, and society chooses how to use them. This understanding is also reflected in modern models of sustainable urban development, where the



interaction between the natural environment and human activity is viewed as a dynamic and interdependent process.

## **MATERIALS & METHODS**

To achieve the objectives of the study, a combination of general scientific and geographical methods has been used, ensuring a comprehensive analysis of urban development and its spatial manifestations. The research is based on the historical approach, through which the evolution of the urban environment and its main stages of development have been traced. This method allows the identification of cause-and-effect relationships between socio-economic changes and spatial structure, related to the study of the emergence of cities.

The spatial approach has been applied in examining the geographical characteristics of the environment in which cities arise and develop. The comparative-geographical method has been used to compare different cities and periods in order to identify similarities and differences in the dynamics of urbanization and territorial organization. The combination of these methods provides a comprehensive and objective analysis of the spatial and functional development of cities, integrating quantitative and qualitative approaches in contemporary geographical science.

## **RESULTS AND DISCUSSION**

### **Leading Geographical Factors in the Emergence and Development of Cities in Antiquity.**

Human civilization arose after a long period of development. It began with the primitive communal system, when humans were entirely dependent on nature, which was also their surrounding environment. During this early period, the creative activity of humans manifested itself as they began to build their own microenvironment. The unification of people into groups to ensure survival and security, access to resources, social needs, and reproduction was the main achievement of the initial stage of the development of human civilization. In antiquity, the grouping of people differed from the contemporary one. It occurred on the basis of complementarity (Gumilev, L.) and depended on the availability of food and water in the respective territory, on the opportunities for the development of crafts and trade, on climatic and geographical conditions, and above all on the need for security and protection.

Among the factors that influenced the formation and development of ancient cities, great importance was held by geographical location, natural conditions, the presence and quantity of raw materials and resources, and the routes for their transportation. The ancient Egyptian civilization developed in the lower course and delta of the Nile River. The Nile Valley provided the population of the cities with sufficient water for drinking and domestic needs, as well as water for agriculture. The annual summer–autumn flooding of the river during the high-water phases (the river's floods) created fertile alluvial soil, very suitable for agriculture, which was naturally enriched every year. The river itself was the main transport artery in the ancient state and the link between the coast and the interior. The population of Egyptian cities consisted of craftsmen, merchants, landowners, state and religious administration, soldiers, and slaves. The large floods, during which the Nile turned into a huge lake a kind of natural disasters were the reason why the Egyptians built their cities on natural or artificially created terraces.

For greater security, they built their temples on the second, higher terrace. The floodplain was used for agriculture. Thus, the most rational rectangular canal network for its time was created, which was also transferred into the concepts of cities (urban planning). The main building materials were brick and clay, so the traces of the constructions from that period have been largely erased. Stone, transported from the territories in the upper course of the Nile, was used only for public buildings – temples, palaces, pyramids, and others. According to their significance and functions, the cities in Egypt can be divided into several groups: capitals, temple cities, commercial cities, and fortress cities. Alongside the cities, a special type of settlements developed, intended for the construction of pyramids, irrigation facilities,



and large palace and temple complexes. Under the influence of the network of irrigation canals, the rectangular street system appeared here for the first time, with the orientation of the streets following the cardinal directions. Such orientation of settlements is also found among other peoples and civilizations on different continents – Europe, America, and Asia.

**The Mesopotamian civilization** arose in the alluvial lowlands between the Tigris and Euphrates rivers. The climate in the upper course of the rivers is mountainous, in the middle course – continental, and in the lower course – subtropical. Similar to Egypt, in Mesopotamia the spring–summer flooding of the rivers provided fertile soil for the development of agriculture, but with the help of irrigation systems. This contributed to the creation of a state organization from the earliest stage of the development of the territory. The cities in Mesopotamia also had a rectangular shape, but unlike Egypt, their orientation followed the intermediate world directions – northwest to southeast.

Characteristic features of Mesopotamian cities are the irregular street network, their construction on terraces, and the building of numerous inner courtyards. The social composition of the population of the cities was similar to that of the ancient Egyptian cities: kings and courtiers, officials, religious servants, craftsmen, merchants, soldiers, farmers, and slaves. In the territory between the Tigris and Euphrates rivers, the city was perceived as something new, given by God, and different from the already traditional ordinary settlements. (Asenov, K. (2024).

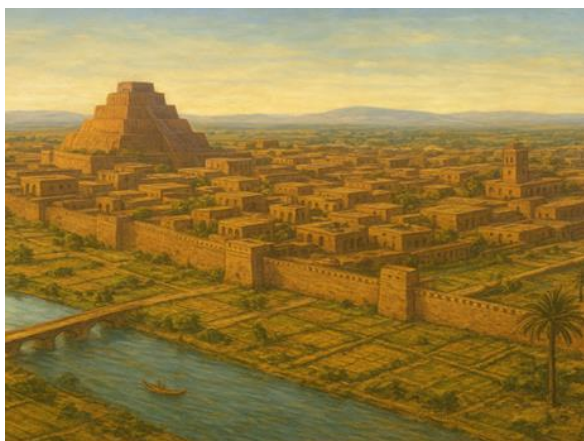


Fig. 1 Model of an ancient city  
Source: AI



Fig. 2 Location of Mesopotamia  
Source: Wikipedia

**The Greek civilization** originated in the southern part of the Balkan Peninsula and gradually expanded to Asia Minor, the Black Sea coast, and parts of the Mediterranean shores. The natural conditions were very diverse. The northern part of Greece was covered with ancient forests and pastures with a predominantly continental climate, suitable for the development of livestock breeding. Central Greece was also forested but had a transitional Mediterranean climate, while in the southern part of the country the climate was Mediterranean, suitable for growing olive groves, vineyards, wheat, and others. Greece was rich in mineral resources – clay, silver, marble, iron, and others. The location of the cities was determined by the search for the most protected sites on rocky hills, inland (Nikolov, P. N. (2019)), with a preference for the southern slopes, which were illuminated by the sun for a longer time, since the natural slope of the terrain ensured the quick drainage of surface waters.

The highly rugged mountainous terrain made communication between the different parts of the country difficult, which necessitated that connections between individual cities be carried out by sea. That is why the Greeks built a large naval fleet since ancient times. In this way, the geography of the territory largely determined a distinctive characteristic of Greek civilization – the mastery of the aquatic area and the development of a coastal civilization. Later, when the military power of the Greeks increased and trade developed, territories located near ports became strategically important, which also influenced urban planning. The cities began to be located on islands, peninsulas, bays, and even straits.

(Jordan Adamson, 2025). Greek civilization gradually developed following the model of the Mesopotamian one – the “City of Palaces,” but on a smaller scale.

Urban planning in ancient Greece advanced significantly with the improvement of the rectangular street system and the formation of a square called the agora. In some cities of ancient Greece, partial water supply and sewerage systems existed. The cities consisted of two parts: the acropolis and the city itself. In some of the city-states of Ancient Greece, the urban population was predominant. The cities that relied more on trade than on conquests were not particularly large. The ancient Greeks were unsurpassed in the skillful integration of the city into the relief and the coastline. They achieved remarkable aesthetic impact with minimal labor expenditure and an optimal combination of defensive and commercial functions.



Fig. 3 Remains of the Acropolis and ancient Greek temples in Athens. *Source: Travelstyle.gr*

**The Roman civilization** dominated the entire Mediterranean basin, with its borders extending north to the British Isles and south to Egypt and Mesopotamia. The natural and geographical conditions within the empire were extremely diverse and included almost all major climatic types. The Roman Empire left traces on the development of settlements and roads throughout almost all of Europe, including in our lands. The Romans improved the existing road network inherited from the Thracians, creating new roads, cities, and fortresses to protect the developing empire. The main military roads were served by specially established small settlements built at a distance of one day’s walking journey. An innovative achievement with important consequences for future spatial organization was the construction of a geodetic coordinate network during this period.

By building this network and properly distributing the land areas, the Romans were able to determine the exact location of every geographical object important to them, in order to create accurate maps (geographical, military road maps, maritime route maps, etc.). Rome represents the pinnacle of ancient urbanization, in which the natural and geographical features of the Apennine Peninsula – favorable climate, availability of construction materials, and access to seas and rivers – created the prerequisites for spatial and infrastructural development. This combination of natural resources and a highly organized socio-political structure allowed the Roman Empire to establish lasting urban models that influenced the subsequent development of European urbanization.

### **Leading Geographical Factors in the Emergence and Development of Cities during the Middle Ages**

The fall of the Roman Empire and the formation, on its territory, of numerous small barbarian states led to the decline of urban culture, architecture, and urban planning. The old Roman cities lost their social and economic significance. During this period, feudal estates replaced cities as the main economic centers. The feudalization of Europe was accompanied by the formation of many small and large kingdoms, duchies, and other state entities. In the organization of their territories, they were entirely subordinated to the will and interests of the ruling dynasty. Thus, many fortress cities emerged, performing commercial, administrative, and defensive functions. They were characterized by a small permanent population that served the ruler and his family. The main part of the population lived in villages and was engaged in farming and animal husbandry.

During this period, citadels also appeared as an integral part of territorial organization – a type of fortress where the ordinary population found refuge during attacks and wars. These, too, were built in naturally fortified locations and possessed infrastructure that allowed the population to survive, including during sieges. (More could be written about the citadels.) The Middle Ages were also marked by another large-scale process – the spread and domination of Christianity and the formation of the Roman Catholic Church as a leading factor in the development of social, political, and economic processes. The Church became the ideological foundation for the establishment, governance, and development of the new feudal system. It was itself among the richest landowners, possessing land, forests, and other resources. It became the initiator of the construction of hundreds of churches and monasteries, some of which developed into economic centers by the end of the period.

The architecture of medieval cities was strongly influenced by the conditions under which they were built – located in inaccessible places, with irregular street networks, narrow and winding streets, and vertical development. During the first period of the Middle Ages, the Romanesque architectural style spread, which is characterized by low and heavy vaults, solid brick or stone walls, few openings in them, and heavy stone towers. Later, by the 12th century, the Gothic style developed, which became particularly widespread in Western Europe. This style originated in Northern France, where some of the most perfect works of Gothic architecture were created.

Medieval cities had a huge impact on the formation of the network, appearance, and structure of modern cities. This applies to the greatest extent to Europe. New cities were not built during the Early Middle Ages. Monasteries were the only centers of material and spiritual culture. They were located near existing settlements, or they themselves became the beginning of new ones. The majority of Western European cities arose not at the monasteries, but around feudal castles. The location for building the castle was chosen for strategic reasons – to be naturally protected: mountainous terrain, rocky inaccessible areas, islands, peninsulas, etc., which were additionally fortified with vertical defensive walls and powerful towers.

From the 12th to the 16th centuries, based on the overall economic development of feudal Europe, there was a revival in urban planning activity. New cities were built in places where trade routes intersected, near mineral deposits, ports, and others. The development of trade and crafts led to the increase of the significance and functions of cities, which began to unite in alliances and fight against feudal dependence. The architecture of medieval cities was strongly influenced by the conditions under which they were built – located in inaccessible places, with irregular street networks, narrow and winding streets.

The initial core from which the development of the medieval city began was the feudal castle, the cathedral, or the market square with the town hall. The defensive walls were round, and the streets were directed radially in all directions. The center of the medieval city, similar to ancient Greek cities, had a dual structure, consisting of the castle located on a high hill and the squares with the town hall, the cathedral, shops, and workshops, which occupied the central place in the city. Public squares were built in front of the town halls. (Kovachev, A, Shishmanova M et al., *The City*, 2014).

The choice of a naturally protected location largely predetermined the planned structure of medieval cities. Their shape and street network closely followed the relief of the terrain, the outlines of



the islands, or the coastline of the peninsulas where they were located. That is why the shape and structure of medieval cities are the most diverse, in contrast to Roman cities, which were largely uniform.



Fig. 4 Carcassonne, Medieval City in France. *Source: History of France* ([www.historia.fr](http://www.historia.fr))

#### **Leading Geographical Factors in the Emergence and Development of Cities during and after the Age of Great Geographical Discoveries (AGGD)**

After the dark era of the Middle Ages, as a result of the rapid development of productive forces and the expansion of large-scale international trade throughout Europe, a revival occurred, which was felt particularly strongly in Italy. The development of manufacturing production and intermediary trade were leading factors in the growth of cities. The Crusades revealed to the Italians the wealthy countries of the East. Wealthy Italian cities conducted active maritime trade with distant countries. On this basis, conditions arose for the rapid development of city-republics – Venice, Florence, Genoa, Milan, and others. Thanks to their central geographical location in the Mediterranean basin, favorable climate, and natural environment, they subjugated the surrounding territories and became not only city-states but also major intermediaries in trade between European states and the Eastern empires. The accumulated wealth allowed them to act as patrons of art and science, which developed favorably and paved the way for the Renaissance.

In the architecture of the urban environment, two new styles emerged – Renaissance and Baroque. The Renaissance represents a revival, continuation, development, and refinement of ancient principles in the art of construction under new socio-economic conditions. This was a period of the emergence of capitalist production relations in Northern and Central Italy and the rise of the urban bourgeoisie, a period of cultural flourishing in the Mediterranean countries – Italy, Spain, France, and later Germany and England, from the 14th to the beginning of the 17th century. The overall progress led to a rapid increase in population, which necessitated large-scale construction in the cities for that time. Thus, urban planning became an important public issue with great scientific and practical significance.

Renaissance urban planning is characterized by the parallel development of theory and practice, with theory preceding practice. This was expressed in the theories regarding the concept of the “ideal city.” At the center of the Renaissance architects’ considerations stood Man, with his

material and spiritual interests. Theorist-urban planners, such as Alberti, Lorini, Scamozzi, Vassari, and others, created theories and plans for building the “ideal city,” which would meet all theoretical and practical requirements. Thus, the first urban planning schemes appeared, which had a purely theoretical character. With them, the theorists of the Renaissance laid the foundation for the science of cities – urban planning.

An example of the ideal city is Lorini, with a main square in front of the ruler’s palace center. On its two sides are located two commercial squares. North of the palace is the exchange square, and south of it is the market square. With the development of trade, the importance of market squares increased. They became the precursor of Renaissance squares, which had an open center. The “San Marco” square in Venice is among the most remarkable works of Italian urban planning art. Cleared of booths and shops, it became the “parade hall” of Venice. This is one of the most beautiful architectural and urban planning ensembles in the world.



Fig. 5 “San Marco” Square in Venice. *Source: Evenice.it*

The theory of ideal cities had a great influence on the planning and construction of cities in France. Among the most famous builders of fortress cities in France was Sébastien Le Prestre de Vauban. Under his leadership, more than 50 fortress cities were built, and twice as many were reconstructed, many of which were located on the eastern border of France. The first French “ideal cities” largely copied the Italian Renaissance models, and later the composition of the plan was modified with the introduction of geometrically regular squares. With the construction of the city of Richelieu, the French broke away from Italian influence and laid the foundations of French classicism. The squares became larger and geometrically regular.

At the end of the 15th century, a new style in art – Baroque was created in Italy, which gradually spread throughout Europe. The strict and calm facades of Renaissance buildings were replaced with complex and highly plastic forms. In the southern countries of Europe, the mild climatic conditions allowed for open squares, gardens, fountains, and long boulevards – typical elements of the Baroque city. Light and sunlight were consciously used as an aesthetic tool to create contrast and impression. The presence of stone and marble deposits, timber, and developed trade in luxury goods facilitated the construction of large-scale and richly decorated buildings. Baroque architects used colored marbles, bronze, gold, and painting for the facades and interiors of buildings.



Fig. 6 St. Peter's Square in Rome. *Source: Linvisibile.com/fr*

Cities differ significantly in their development and size. Their identity, although rooted in history, continuously changes. Over time, most cities have undergone evolution driven by new needs, ideals, lifestyle, living standards, and quality of life (Shishmanova & Karadzhev, 2015).

A powerful impetus for urban development was provided by the Great Geographical Discoveries and the colonization of the New World, the creation of centralized states, and bourgeois revolutions. The discovery of America and the sea route to India shifted the most important routes of world trade. The Mediterranean Sea became a closed sea, an arena of military confrontation between the Christian states and the Ottoman Empire. Spanish and Portuguese colonization focused on building fortress cities both along the coast and in the interior of the newly discovered continent, completely destroying the existing Indian cities. The general upsurge led to a rapid increase in population. This necessitated very large-scale construction in the cities. Theorist-urban planners, such as Alberti, Lorini, Scamozzi, Vassari, and others, created theories and plans for building the “ideal city,” which would meet all theoretical and practical requirements.

#### **Leading Geographical Factors in the Emergence and Development of Cities under the Influence of Industrialization**

The development of industry and the release of labor from the agricultural sector led to the concentration of population in cities and their rapid growth. The expansion of cities resulted in serious demographic, structural, and economic changes that even modern cities struggle to cope with (Jonatan Andersson, Jakob Molinder, Vol. 148, July 2025, 103772). Many new industrial enterprises were established mainly in areas rich in mineral resources, which became the nuclei of new urban settlements or future industrial zones adjacent to existing ones. In coastal areas, the construction of port infrastructure also played a localizing role in shaping industrial centers, accompanied by the utilization of space for the development of urban settlements.

The crossroad's geographical location also favored the development of urban settlements with predominantly commercial functions at first, which were later supplemented by industrial and other functions. The growth of cities occurred at the expense of the massive migration of the rural

population. An important role in the development of cities was played by the emergence and development of railway transport (Sazonov, Sergey Leonidovich). The major European cities became centers of the wealthy bourgeoisie, which radically changed their appearance. The construction of industrial zones on the outskirts of cities and the spontaneous building of residential neighborhoods led to environmental pollution. This necessitated the creation of the first legal and legislative frameworks to regulate urban construction, planning, and better city management, as well as the accumulation of financial resources for their improvement.

Until the 20th century, the development of cities was characterized by a certain balance. The twentieth century, as the century of the scientific and technological revolution, led to the accelerated development of urbanization on a global scale. As a result, there was a spontaneous territorial and demographic expansion of large cities and a complication of their planning and spatial structure (Kovachev, 2003).

### **Leading Geographical Factors in the Emergence and Development of Cities in Bulgaria**

The Bulgarian lands, with their geographical location and favorable natural conditions, were very suitable for the development of the economy and culture of the peoples who inhabited them.

Systematic archaeological excavations prove that settlements existed on the territory of Bulgaria since ancient times. The earliest traces of human presence in Bulgarian lands date back to the Middle Paleolithic period (100,000–40,000 BC), corresponding to the Riss glacial period. Due to the cold and harsh climate, and in order to protect themselves from natural forces, humans lived in caves and under rock overhangs. The caves in the Gabrovo region, inhabited by humans since ancient times, are numerous. Their greatest concentration is along the valleys of the Yantra, Rositsa, Dryanovska, and Loposhnitsa rivers, and around the Dryanovo Monastery. Among them are the Bacho Kiro Cave, Momina Cave, Polichkite, and others (Milchev, Atanas, 1979).

The discovered remains – bone and antler tools, fragments of clay vessels, bones of deer, cave bears, and other animals, as well as two human teeth belonging to a Cro-Magnon-type person – from the inhabitants of the “Bacho Kiro” Cave date back to the middle period of the Old Stone Age (approximately 70,000–40,000 BC) (Hublin, J.J., Sirakov, N., Aldeias, V. et al., 2020; Hajdinjak, M., Mafessoni, F., Skov, L. et al., 2021).

Archaeological excavations in the Devetashka Cave (Lovech Region) provide evidence of the early stages of human settlement in the area, dating back to the Old Stone Age, with the earliest traces of human activity originating from the Middle and Late Paleolithic (approximately 200,000 – 10,000 BC) (Georgiev, G.). During this period, the cave served as a shelter and dwelling for hunter-gatherers, which is confirmed by the discovered flint tools as well as animal remains that were used for food. The bone tips of spears and arrows found in the cave indicate progress in hunting technologies and weapon-making. Although these findings belong to the Paleolithic period, the Devetashka Cave is also an important site for studying the transition to later historical stages.

Of archaeological significance are also the discoveries from the Neolithic (New Stone Age) period, dating from around 6200 to 4900 BC, when human life began to change with the development of agriculture and the emergence of permanent settlements. In the Devetashka Cave, fragments of clay vessels, stone axes, and ceramic tools have been discovered, confirming the existence of early agricultural and craft practices. The presence of furnaces also testifies to the development of primary economic structures in the region. With a length of almost 2 km and a height reaching up to 38 m in some places, it is one of the longest caves in Bulgaria and also offers a number of geographical and ecological advantages that made it suitable for human habitation.

It is located on the southern slopes of the Central Balkan Mountains, near the Osam River, which contributed to the supply of water and the availability of various resources. These conditions allowed both the hunting-gathering economy and, later, agriculture to develop. During the Chalcolithic period, also known as the Copper-Stone Age, the cave became almost fully inhabited. Archaeological findings indicate that people not only used the cave as a shelter but also began to build permanent dwellings within it, which shows the development of social structures and architectural practices. The Devetashka



Cave and the discoveries made there provide valuable data about the historical and geographical development of the region. They demonstrate how human societies adapted to the natural conditions of the Balkans while also highlighting the importance of this area as a significant cultural and geographical center during the prehistoric stages of human evolution (B. Mihaylova, K. Kostov, 2024; Alexey Zhalov).

During the Eneolithic period, the spatial organization of life in northeastern Bulgaria was strongly dependent on the natural environment and geographical conditions. The Varna region became a key center because it combined a protected coastline, waterways, and access to valuable resources. The stilt settlements near the Varna and Devnya basins arose on wooden structures in the shallow waters of lakes and the bay. This form of settlement was dictated by geographical conditions – the water provided protection while also enabling transportation and communication.

The concentration of population in such large settlements was unparalleled in the Balkans at that time. The existence of the Varna civilization is inconceivable without resources from different geographical regions. Provadia, located inland, was a center for salt production. In the basin with rich salt deposits, salt was produced and shaped into ingots, which were transported via the Provadiya River to the Varna Bay. Meanwhile, the southern Black Sea coast and the Strandzha region were rich in copper ore, which was transported by sea to the same region.

Thus, Varna became a geographical hub where raw materials – salt and copper – converged, giving rise to a metalworking center. Varna's location on the Black Sea connected it to extensive trade routes. From here, copper and gold products were exported northward to Durankulak, and further to Ukraine, Romania, Moldova, and Slovakia. Southern routes enabled exchange with other centers along the Black Sea coast. Geography therefore defined Varna's role as an intermediary between the inland resources of the Balkans and the extensive contacts across the Black Sea basin and Central Europe. This combination of inland wealth, coastal location, and convenient transport links created the unique foundation of the Varna civilization, making it one of the earliest economic and cultural centers of the Old Continent.



Fig. №7 Aerial view of the Provadia Settlement Mound. *Source: Provadia-Solnitsa*  
(<https://www.provadia-solnitsata.com/bg>)

Remains of human activity dating back to the fifth millennium BCE have been found in the eastern parts of the Rhodope Mountains, at the archaeological complex of Perperikon, located near the village of Gorna Krepost, in the valley of the Perperishka River. Perperikon is the largest and

best-preserved rock sanctuary in the Rhodopes and an important geographical and cultural center of the region (Asenov, K., 2024). The geographical context of Perperikon is unique. The rock complex is situated on Hisar Tepe hill, which is part of the Rhodopes – an area known for its strategic location, rich natural resources, and sacred sites. This mountainous region is extremely rich in gold, which was also a factor in the development of ancient civilizations. Gold extraction around Hisar Tepe hill, near the village of Stremtsi, was of fundamental importance for the economic activity in the area during various historical periods. Perperikon existed through different eras: Late Chalcolithic, Bronze Age, Iron Age, Hellenistic and Roman periods, as well as Late Antiquity and the Middle Ages.

The inhabitants of this geographical area chose to build their settlement on a rocky elevation, which not only offered strategic advantages for observation and defense but also symbolized their religious connection with the Sun. The rocky location provides a wide view of the horizon, from which the rising of the Sun can be observed, forming part of their religious cult. The architectural structure of Perperikon is organized on three levels: the Acropolis, the fortified palace-sanctuary, and the suburbs, located to the north and south. The temples and rock constructions in the region are carved directly into the stone of the hills surrounding the city. This unique architecture is part of the broader cultural and geographical context of the region, which during the Late Bronze Age was connected with the development of the first European civilization. Ancient Perperikon and its geographical significance serve as a symbol of one of the earliest and most complex cultures in Southern Bulgaria, which has a direct connection to the specific natural and geographical conditions of the Rhodopes.

Consequently, in the territory of the Balkan Peninsula, including present-day Bulgarian lands, the natural environment played a decisive role in the emergence and development of settlements. The presence of various mineral resources, the availability of water sources for drinking and domestic needs, water basins, and favorable soil and climatic conditions had a localizing function regarding the establishment of settlements and the scale of population growth, as well as their development as economic centers in antiquity and later. The natural protection offered by the relief in relation to the settlements was also very important.

During the ancient and medieval periods, the territories we today know as Bulgarian lands occupied a central position on the Balkan Peninsula. They consist of three main historical-geographical regions: Moesia (present-day Northern Bulgaria), Thrace (present-day Southern Bulgaria), and Macedonia. This key location determined their role as a strategic bridge between Europe and Asia. Such a geographical position facilitated both trade and cultural interactions, but it also made them a target for numerous migrations and military campaigns (Tsenova, E., 2014).

The Thracian civilization is one of the oldest and most significant cultures to have inhabited the present-day Bulgarian lands. Material evidence, such as archaeological finds, tombs, and sanctuaries, allows for a partial reconstruction of the geographical extent and spread of Thracian culture. These serve as a primary source for mapping the territories of different tribes and for establishing their relationship with the landscape, natural resources, and trade routes. It is believed that the Thracian ethnic community formed during the 2nd millennium BCE as a result of the merging of the local Balkan population with tribes from the north and south. They were organized into numerous tribes, among the most well-known being the Odrysians, Getae, Triballi, and Bessi.

The Thracian economy was primarily based on agriculture and animal husbandry. Particularly advanced were the crafts related to metalworking, including the extraction and processing of precious metals such as gold and silver. By the 8th–7th centuries BCE, although the dominant social structure was still clan-based, the Thracians began to form more complex state structures. The unification of a large part of the tribes along the Maritsa River led to the creation of the Odrysian Kingdom, with its capital at Odrysa, and later at Seuthopolis. This was a key moment in the development of Thracian civilization, as it marked the transition from a tribal to a state model of governance, which was an important factor in their relations with neighboring peoples.

Remains of significant urban centers have been discovered, exhibiting the typical dual structure of antiquity: a ruler's fortress (*located on a high, strategic site – a hill or rocky promontory*) and a city for the people (*situated in the flatter area around the fortress, with convenient access to roads, water*



*sources, and agricultural land*). The cities featured a rectangular street network but had irregular shapes, surrounded by high defensive walls with watchtowers. With the onset of Greek colonization, the Black Sea coast began to develop, with city layouts adapted to the terrain. In present-day Bulgaria, some of the most significant archaeological finds related to Thracian civilization have been discovered, many of which are now included in the UNESCO World Heritage List. Among the most impressive monuments are the Thracian tombs in the "Valley of the Thracian Kings" in the Kazanlak Valley, renowned for their exquisite murals.

Bulgaria is also home to some of the most beautiful and richly decorated Thracian treasures, showcasing the extraordinary skill of the ancient Thracians in working with gold and silver. Notable examples include the Panagyurishte (gold), Rogozen (silver), and Valchitran treasures. Remains of Thracian cities have also been discovered, such as Seuthopolis, the capital of King Seuth III, which today lies beneath the waters of the "Koprinka" reservoir, as well as fortresses and sanctuaries like those in Perperikon and Starosel.

By the end of the 5th century, the entire Balkan Peninsula had been conquered by the Romans, who undertook extensive construction activities. The Romans did not merely conquer the territory; they organized and transformed it according to its geographical features. The Danube River became the natural northern boundary of the empire and of the province of Moesia. The Balkan Mountains (Hemus) served as a natural barrier and a border between the provinces of Moesia to the north and Thrace to the south. The Romans expanded settlements near warm mineral springs, demonstrating their appreciation of natural resources.

Cities such as Sofia (Serdica) and Kyustendil (Pautalia) owed their prosperity precisely to their mineral springs. The construction of roads represented the greatest geographical transformation. They connected newly established cities, military camps, and economic zones. This network "shortened" distances, facilitated trade and troop movements, and integrated the Balkans into the economic and military geography of the entire empire. The creation of cities with a rectangular layout was an attempt to impose order and standardize the appearance of settlements. This changed the population map—from predominantly rural, it became more urban, with clearly defined administrative, military, and economic centers. The Roman Empire skillfully utilized the geography of the territory (rivers, mountains, springs) for its administrative and strategic purposes while simultaneously creating a new socio-economic geography through roads and cities (Á. Vanessa, 2013, pp. 125–140).

In the 5th–6th centuries, Slavic tribes settled on the Balkan Peninsula, mainly occupying the fertile lowlands and valleys along the Danube and Maritsa rivers, pushing the local Thracian population to the more inaccessible mountainous regions. At the same time, from the steppes of Asia, movements toward Europe began by the Proto-Bulgarians, who proceeded along the path to the Balkans and became part of the process of forming the new ethnic and political map of the region. The Proto-Bulgarians, also known as a horse-riding people, lived in yurts and tents, which were easily adapted to the steppe geographical environment. The yurt was a portable round tent, covered and insulated with skins. Their livestock-based way of life required constant movement due to the grazing needs of the herds. In the 7th century, the Proto-Bulgarians and Slavs established the first Bulgarian state on the Balkan Peninsula, whose borders were outlined by rivers, mountains, and the Black Sea, providing natural protection and control over fertile lands and trade routes. The new state occupied the lands from the Eastern Carpathians in the north to the Balkan Mountains in the south, and from the Timok and Iskar rivers in the west to the Black Sea and the Dnieper River in the east.

The urban development of the First Bulgarian State developed based on the construction traditions of the Slavs and Bulgarians. The destroyed ancient cities were restored, and extensive construction of new fortresses and public buildings for the needs of the state and churches was carried out. The first Bulgarian capital, Pliska, was built on a flat terrain with the shape of an irregular quadrangle and a division into an inner and outer city. In the inner city were located the khan's palace, a small church, the residences of the boyars, and economic buildings; between the inner and outer city – barracks, workshops, and more than 30 small churches; and in the outer city



– the large Preslav Basilica, which reflects functional zoning and the socio-administrative organization of the early Bulgarian state.

A true flourishing of construction and culture occurred under Simeon I (893–927), who moved the capital from Pliska to Preslav. The second Bulgarian capital, Preslav, was built near the Balkan Mountains, by the Ticha River. The city's shape was irregular, with two stone fortress walls. Bulgarian cities of this period generally bore the characteristics of medieval cities: location on naturally defensible sites, irregular street networks, and a two-part fortress structure. The first and second capitals of the Bulgarian state were situated on flat terrain and were planned very spaciouly, with considerable open space between the inner and outer fortress walls, which was highly atypical for medieval cities in Europe. Historians explain this with the military organization of the Bulgarians, whose main strength was cavalry.

The most prominent among Bulgarian cities was Veliko Tarnovo, the capital of the Second Bulgarian State. The city's location on the two hills, Tsarevets and Trapezitsa, was chosen with a view to effective defense against enemy attacks. On Tsarevets were located the royal palaces, fortified with walls and defensive towers. There was a large throne hall, a palace church, and various residential rooms. On Trapezitsa were located many boyar churches. Alongside the restored monasteries from the First Bulgarian Empire, new monasteries also began to be built. During the time of the Second Bulgarian State, architecture and construction reached a great flourishing. Cities were built on strategically defensible sites – hills, along rivers, and on the Black Sea coast. Other important cities such as Sredets (Sofia), Mesembria (Nessebar), Vidin, Preslav, Yambol, Targovishte, and Lovech served as administrative, military, and trading centers, with their locations providing control over the territory, access to trade routes, and natural defense.

The flourishing of Bulgarian cities did not last long. In 1393, Bulgaria fell under Ottoman rule, which lasted about five centuries and brought severe Ottoman domination. During the Ottoman period, Bulgarian cities lost much of their medieval administrative and military significance, with many fortresses being destroyed and/or depopulated. Some retained a role as commercial and craft centers, especially those located on major rivers, important roads, and along the Black Sea, but the social, economic, and religious structure changed through the construction of mosques, baths, and administrative buildings of the Ottoman Empire.

Under Ottoman rule, Bulgarian cities and settlements acquired a typical Oriental medieval appearance, with narrow and winding streets, low-rise houses, mosques, and minarets. Wealthier residents built houses with thick walls for protection against attacks (for example, in Arbanasi and Vratsa). The cities turn into commercial-administrative and artisan centers, where mainly Turks, Greeks, Jews, and foreign merchants settled, and the Bulgarians remain mainly craftsmen. The villages and mountain regions remain inhabited mainly by Bulgarians, engaged in agriculture, livestock breeding, and craftsmanship. In some predominantly mountainous territories, entirely Bulgarian settlements arise. The cities and settlements are organized into cities, small towns (palankas), villages, and neighborhoods, and trade is concentrated in bazaars, which are lively during the day and close in the evening, with time regulated by clock towers.

At the beginning of the 19th century, order in the Bulgarian lands was restored through the introduction of a regular army, which allowed the development of production, trade, and construction, including the building of railway lines, bridges, roads, and public buildings. In this period, a revival of culture and education began, with the opening of the first Bulgarian schools (Gabrovo, Elena) and the introduction of worship in a language understandable to the people. Church and cultural independence stimulated the construction of churches and monasteries (including the Rila Monastery).

During this period, the Bulgarian Revival culture emerged, developed, and took shape, including architecture and urban planning. The construction of churches, houses, schools, fountains, bridges, and others changed the appearance of Bulgarian settlements. Even without preliminary plans, the settlements were built as ensembles. Examples of this are Melnik, Plovdiv, Koprivshtitsa, Tryavna, Elena, Smolyan, Tarnovo, Dryanovo, and others.



With the restoration of the Third Bulgarian State, the so-called post-liberation period begins. The Main Directorate of Public Buildings is created to regulate construction issues. Intensive construction of roads, railway lines, ports, banks, factories begins, and foreign capital enters Bulgaria massively. Many specialists also come from abroad, including architects and engineers. The first specialists working in our country were the Russian engineers who remained after the war. In 1878–79, they made a cadastral survey of Sofia, and later developed the first regulatory plan of the city, which contained only the street network and a few public buildings. The development of capitalism pushed cities to the forefront and quickly turned them into the main type of settlements, which rapidly increased their population. Natural advantages such as location along main roads, railway lines, and raw material deposits gave an additional boost to the development of some cities. They also developed as leading centers of industry – Sofia, Plovdiv, Ruse, Varna, Burgas, and others.

The Revival Balkan settlements declined, which in turn allowed their heritage to be preserved. In 1897, the first Law on the Improvement of Settlements was drafted, which required all cities to be provided with regulatory plans. From the Turkish rule, Bulgaria inherited settlements with irregular street networks, with the exception of Orhanie (Botevgrad). Mass “straightening” of the street network and modernization of the settlements began. Recent studies indicate that the integration of information and communication technologies significantly influences tourism and spatial organization, supporting the evolution toward smart, sustainable destinations (Lile, Kalluçi & Kaçurri, 2025). The Revival urban planning heritage was being destroyed wholesale. Construction in the cities, and especially in their centers, had a speculative character and led to a deterioration of hygiene. The cooperative residential buildings that emerged after the First World War represent a progressive Bulgarian tradition. The large cities were composed of poor working-class outskirts and well-organized centers.

The period after 1944 is directly connected with clearing the ruins, restoring the destroyed capital Sofia, and carrying out a number of measures to strengthen the socialist economy. The adoption of the Law on Land Ownership provided land to a large number of landless and poor peasants. After that, the nationalization of industrial enterprises was carried out, a new constitution was drafted, and the first two-year national economic plan was composed. Mainly the existing enterprises were restored, and the construction of some new enterprises began, but still on a limited scale, in accordance with the not yet consolidated economic power of the country.

During this period – from 1944 to 1948 – active urban planning and survey activities also began. Industrialization of the country began. The large complex of buildings of the Chemical Plant in Dimitrovgrad, the Metallurgical Plant in Pernik, the numerous non-ferrous metal mines and flotation factories in the Rhodope mining basin, and others, became pioneers of industrial development and construction in the country. In connection with the new industrial centers, new cities and settlements also grew–Dimitrovgrad, Madan, Rudozem, and others. With the construction of the Sofia Thermal Power Plant, the “V. Kolarov” dam in the Rhodopes, the “Al. Stamboliyski” dam on the Rositsa River, the “G. Dimitrov” dam on the Tundzha River, and others, the energy base of the country also began to develop. Separate enterprises were built in the cities, for example, the “Ernst Thalmann” spinning factory in Sofia. At this time, the complete cooperation of agriculture was also carried out.

The image of a large part of contemporary Bulgarian settlements bears the marks of Thracian and Slavic settlements, of ancient Greek and ancient Roman settlements, of the settlements from the First and Second Bulgarian States, of the Turkish rule, and the Bulgarian Revival, as well as of their development during the twentieth century. The layering of these cultures gives the richness and diversity in the composition of Bulgarian settlements, their uniqueness, and at the same time their indisputable belonging to European civilization. That is why the problem of the settlement network, of its condition and development prospects, is very relevant for Bulgaria, which is undergoing complex and rapid socio-economic changes. Similar technological influences have been observed in virtual environments, where digital transformation reshapes regional sustainability and spatial perception (Karadzhov & Kirilov, 2023).



During the period of socialist development and the centralized planned economy, the role of spatial planning increased significantly. A Law on Territorial and Settlement Organization was adopted, territorial-organization, urban planning, construction, and regulatory plans were developed, as well as a General Scheme for the Territorial Distribution of Productive Forces and a Unified Territorial-Organization Plan (UTOP) for the state territory. With it, the planned-normative economic and social prerequisites are combined to ensure equal living conditions in the settlements of the country. (Almanac Scientific Research 2017).

## CONCLUSION

The development of cities during different historical periods clearly shows the dependence between the natural environment and urbanization. Specific characteristics and features of the climate, relief, soil and water resources, and the presence of raw material deposits determine the location, pace of development and prosperity, structure, and functions of the settlements. From ancient civilizations to the industrial era, geographical factors remain key for the formation of urban economic centers. With the development of society, socio-economic and technological processes gradually become dominant, but the natural foundation continues to influence the sustainability and planning of cities, as well as the ecological parameters of the urban environment.

Not only in a historical context, but also in their contemporary development, cities reflect the continuous process of interaction between humans and nature. The knowledge, study, and management of processes in the urban environment begin precisely in the extra-urban environment, which to a lesser or greater extent is natural. Therefore, the significance of this environment, in which cities develop, and the changes that occur in it, necessarily influence the present and future development of cities. That is why the interaction between them remains relevant for contemporary concepts of sustainable urban development.

## REFERENCES

- Adamson, J. (2025). Trade and the rise of ancient Greek city-states. *Journal of Economic Behavior & Organization*. <https://www.sciencedirect.com/science/article/pii/S0167268125001544>
- Andersson, J., & Molinder, J. (2025). ). Did cities increase skills during industrialization? Evidence from rural-urban migration. *Journal of Urban Economics*, 148, Article 103772. <https://doi.org/10.1016/j.jue.2025.103772>
- Asenov, K. (2024). Metaphysics of the City: Urban Genesis and Mythology (Part One). *Problems of Geography*, 1, 2. <https://d1wqtxts1xzle7.cloudfront.net/118425585/>
- Bulgarian Academy of Sciences. (2016). Devetashkata Peshtera. *Otechestvo Lyubezno*. <https://priroda.bas.bg/wp-content/uploads/2025/07/br2-2016-14.pdf>
- Clark, P. (2009). *European Cities and Small Towns: 400–2000*. Oxford University Press.
- Ernste, H., & Philo, C. (2009). Determinism / Environmental Determinism. In R. Kitchin & N. Thrift (Eds.), *International Encyclopedia of Human Geography* (pp. 102–110). Elsevier. <https://doi.org/10.1016/B978-008044910-4.00677-5>
- Evenice. (n.d.). Piazza San Marco. <https://venice.it/venezia/piazza-san-marco>
- Garvanov, I., Slavova, S., Marinkov, Z., & Momchilov, G. (n.d.). *Fractal Structures in Ancient Cities of India*.
- Georgiev, G. (1960). Major Periods in the Development of Culture during the Neolithic and Copper Age in Bulgaria in Light of the Latest Archaeological Research. *Światowit*, 23, 309–339. <https://bazhum.mużhp.pl/media/texts/...>



- Ganev, H. (1992). Trends in Demographic Development of Urbanization and Urban Agglomerations in Bulgaria. *Yearbook of Sofia University, Book 2 – Geography, Vol. 80*.
- Ganev, H. (1993). The Influence of “Center-Periphery” on Population Dynamics in the Settlements of the Sofia Agglomeration. *Bulletin of the Bulgarian Geographical Society, XXVIII (XXXVIII)*.
- Hublin, J. J., Sirakov, N., Aldeias, V., et al. (2020). Early Upper Paleolithic Homo sapiens from Bacho Kiro Cave, Bulgaria. *Nature, 581*, 299–302. <https://doi.org/10.1038/s41586-020-2259-z>
- Haydinyak, M., Mafesoni, F., Skov, L., et al. (2021). Early Upper Paleolithic Humans in Europe had Recent Neanderthal Ancestry. *Nature, 592*, 253–257. <https://doi.org/10.1038/s41586-021-03335-3>
- Historia.fr. (n.d.). The Medieval City of Carcassonne. <https://www.historia.fr/guide-culture-loisirs/tourisme/la-cite-medievale-de-carcassonne-2067481>
- Influence of Roman Public Administration on Modern Regulation of Construction and Use of Public Roads. (n.d.). <https://www.cceol.com/search/book-detail?id=1130597>
- Karadzhev, V., & Kirilov, S. (2023). Virtual Horizon – Unveiling the Ecological Impact of Virtual Tourism. *Pirinski Knizhovni Listi, 14*, 38–49. <https://doi.org/10.5281/zenodo.14708193>
- Kovachev, A. (2003). Градоустройство: Част II [Urban Planning, Part II]. Sofia, Bulgaria: Pensoft Publishers.
- Kovachev, A., & Shishmanova, M. (2014). Градът / The City. Sofia, Bulgaria, Publisher: Gea Print.
- Lile, A., Kalluçi, E., & Kaçurri, A. (2025). The Impact of ICT on Active Tourism: A Systematic Literature Review of Innovation, Smart Tourism, and Sustainable Development. *International Journal of Digital Research, 1(3)*, 46–52. <https://doi.org/10.63711/ijdr.net20250305>
- Linvisible. (n.d.). Baroque Architecture – Exploration by Linvisible. <https://linvisible.com/fr/actualites/linvisible-exploration-architecture-baroque/>
- Mechnikov, L. I. (1898). Civilization and the Great Historical Rivers: Geographical Theory of the Development of Modern Societies (translated by M. D. Grodetsky). *St. Petersburg: Life*.
- Mihaylova, B., & Kostov, K. (2024). Engineer Pavel Petrov (1884–1984) and His Contribution to Bulgarian Hydrogeology and Speleology–140 Years Since His Birth. *Review of the Bulgarian Geological Society, 85(2)*, 220–224. [https://bgd.bg/REVIEW\\_BGS/REVIEW\\_BGD\\_2024\\_2/PDF/40\\_Mihaylova\\_REV-BGS\\_2024-2.pdf](https://bgd.bg/REVIEW_BGS/REVIEW_BGD_2024_2/PDF/40_Mihaylova_REV-BGS_2024-2.pdf)
- Milchev, A. (1974). Gabrovo and Its District during the Prehistoric and Ancient Periods. *Yearbook of Sofia University “St. Kliment Ohridski”–Faculty of History, 68(1)*, 369–457. <https://doi.org/10.60053/GSU.IF.1.68.369-457>
- Nikolov, P. N. (2019). Evolution of Urban Form and Sustainable Planning of Transport-Communication Systems. In *Proceedings of the IX International Scientific Conference “Architecture, Construction – Modernity”, Varna, Bulgaria*.
- Nikolov, V. (2021). Spatial Structure and Chronological Development of the Prehistoric Salt Production Complex Provadia–Solnitsata. *Istoriya, 29(3)*, 223–243. <https://www.cceol.com/search/previewpdf?id=986610>
- Patarchanov, P., & Petrov, K. (2021). Socio-Demographic Portrait of the Cities. *Yearbook of Sofia University, Geology and Geography Faculty, Book 2, Geography, 113*, 204–222. [https://www.uniofia.bg/index.php/bul/universitet\\_t/fakulteti/geologo\\_geografski\\_fakultet/oficialni\\_izdaniya/kniga\\_2\\_geografiya\\_tom\\_113](https://www.uniofia.bg/index.php/bul/universitet_t/fakulteti/geologo_geografski_fakultet/oficialni_izdaniya/kniga_2_geografiya_tom_113)
- Popov, S. (n.d.). Economic Foundations of the Varna Civilization. [https://su-varna.org/izdaniy/Kultura-12/pages\\_06\\_17.pdf](https://su-varna.org/izdaniy/Kultura-12/pages_06_17.pdf)
- 



- Popov, S. (n.d.). The End of the Chalcolithic Civilization of Varna in “Greek” and Egyptian Mythology. <https://www.istor-konf-varna.com/publikacii/%D0%9F%D0%BE%D0%BF%D0%BE%D0%B2-%D0%9A%D1%80%D0%B0%D1%8F%D1%82%20%D0%BD%D0%B0%20%D1%86%D0%B8%D0%B2%D0%B8%D0%BB%D0%B8%D0%B7%D0%B0%D1%86%D0%B8%D1%8F%20%D0%92%D0%B0%D1%80%D0%BD%D0%B0.pdf>
- Popov, S. (n.d.). Varna as a Maritime Transport Center in the Early Bronze Age. *Cultural Heritage of Varna and the Black Sea Region*, 1, 44–54. <https://www.cceol.com/search/article-detail?id=1134422>
- Sazonov, S. L. (2013). Transport. In People’s Republic of China: Politics, Economy, Culture 2012–2013 (pp. 148–159). <https://www.elibrary.ru/item.asp?id=24037386>
- Shishmanova, M., & Karadzhev, V. (2015). Trends for Sustainable Development of Rural Areas in Bulgaria. In *Proceedings of the International Scientific Conference "Contemporary Development of European Rural Areas"*, Zadar, Croatia (pp. 55–63). ISBN 978-953-331-065-7.
- Tsenova, E. (2014). Space and Functional Aspects of the Central City Square in Lower Moesia and Thrace within Modern Bulgaria (1st–3rd Century): *Doctoral Dissertation Abstract*. New Bulgarian University. <https://eprints.nbu.bg/id/eprint/2974/1/avtoreferat-em-tsenova.pdf>
- Wikipedia. (n.d.). Mesopotamian Lowlands. [https://bg.wikipedia.org/wiki/Месопотамска\\_низуина](https://bg.wikipedia.org/wiki/Месопотамска_низуина)

#### **How to cite this article:**

Filatova, E., & Patarchanova, E. (2025). Geographical Studies of Urbanization Processes and Their Spatial Organization in Bulgaria. *International Journal of Digital Research*, 1(3), 110–127. <https://doi.org/10.63711/ijdr.net20250309>

\*\*\*\*\*

