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How to Create the Best NOISE Analysis

A Practical Framework for Strategic Decision-Making

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ABSTRACT

This study proposes a standardized methodological framework for conducting NOISE analysis, addressing the limited conceptual development and lack of structured application of this underutilized strategic tool. While widely used analytical models such as SWOT, PESTEL, and SOAR provide valuable insights, they often exhibit limitations related to descriptive orientation, insufficient integration of action planning, or imbalance between internal and external factors. The NOISE framework – comprising Needs, Opportunities, Improvements, Strengths, and Exceptions – is introduced as a hybrid analytical model that integrates diagnostic and solution-oriented perspectives. The study develops a step-by-step methodology, including factor identification, categorization, evaluation, prioritization, and strategy formulation. A scoring system is proposed to enhance analytical rigor and support decision-making. To demonstrate its applicability, the framework is illustrated through a realistic case of a higher education institution undergoing digital and organizational transformation. The results highlight the capacity of NOISE analysis to bridge the gap between analysis and implementation, enabling the formulation of targeted and actionable strategies. The findings suggest that NOISE analysis represents a flexible, balanced, and implementation-oriented alternative to traditional frameworks. The study contributes to the advancement of strategic management methodologies by providing a clear, replicable, and adaptable analytical model applicable across multiple sectors. Future research directions include empirical validation, integration with quantitative models, and application in emerging domains such as digital transformation and sustainability.

Keywords: *Noise analysis, Strategic analysis, Decision-making, Organizational development, Strategic management, Analytical frameworks*

INTRODUCTION

In contemporary strategic management and organizational analysis, structured analytical frameworks play a crucial role in supporting decision-making processes across diverse sectors (Porter, 1980; Mintzberg, 1994; Bryson, 2018). Widely recognized tools such as SWOT, PESTEL, and SOAR analyses have been extensively applied in business, public administration, tourism, and regional development due to their ability to synthesize complex internal and external factors into actionable insights (Gürel & Tat, 2017; Yüksel, 2012). However, despite their widespread use, these models often exhibit limitations related to overgeneralization, insufficient focus on implementation, or an imbalance between diagnostic and forward-looking components (Hill & Westbrook, 1997).

In response to these limitations, alternative analytical frameworks have emerged, aiming to provide more nuanced and operational perspectives. One such model is the NOISE analysis, which focuses on Needs, Opportunities, Improvements, Strengths, and Exceptions. Unlike traditional deficit-oriented approaches, NOISE analysis integrates both problem identification and solution-oriented thinking, offering a more dynamic and flexible structure for strategic evaluation.

Despite its conceptual potential, NOISE analysis remains relatively underdeveloped in academic literature. Existing applications are often fragmented, lacking a standardized methodological approach, clear procedural steps, and consistent criteria for implementation. This gap limits its broader adoption and reduces its effectiveness as a reliable analytical tool in both academic and professional contexts.

The present study aims to address this gap by proposing a comprehensive and standardized framework for conducting NOISE analysis. Building upon previous methodological contributions in strategic analysis (e.g., SWOT, PESTEL, and SOAR), this paper introduces a structured approach that enhances clarity, applicability, and analytical rigor. The proposed framework is designed to support researchers, practitioners, and policymakers in systematically identifying key strategic factors and translating them into actionable decisions.

The main contributions of this study are threefold. First, it conceptualizes NOISE analysis within the broader landscape of strategic management tools. Second, it develops a step-by-step methodology for conducting NOISE analysis, including clear definitions, categorization criteria, and practical guidelines. Third, it provides a foundation for future empirical applications and comparative studies, positioning NOISE analysis as a viable and competitive alternative to more established frameworks.

CONCEPTUAL FOUNDATIONS OF NOISE ANALYSIS

Strategic analytical frameworks have evolved significantly over the past decades, reflecting the increasing complexity of organizational environments and the need for more adaptive and actionable decision-making tools (Mintzberg, 1994; Grant, 2016). Classical models such as SWOT analysis have traditionally focused on the identification of internal and external factors, while later frameworks, including PESTEL and SOAR, have introduced broader contextual and more positive, forward-looking perspectives. Despite these advancements, many analytical approaches remain either overly diagnostic or insufficiently oriented toward practical implementation.

Within this evolving landscape, NOISE analysis emerges as a relatively underexplored yet conceptually promising framework. The acronym NOISE represents five key dimensions: **Needs, Opportunities, Improvements, Strengths, and Exceptions**. Unlike traditional deficit-focused models, NOISE analysis integrates both problem identification and solution-oriented thinking, offering a more balanced and dynamic approach to strategic evaluation.

Theoretical Positioning of NOISE Analysis

NOISE analysis can be situated at the intersection of diagnostic and appreciative analytical frameworks. While SWOT analysis emphasizes the classification of internal and external factors, it has often been criticized for its static nature and limited capacity to guide implementation (Pickton & Wright, 1998; Gürel & Tat, 2017). Similarly, PESTEL analysis provides a comprehensive overview of macro-environmental influences but does not inherently translate findings into actionable strategies (Karadzhov & Patarchanova, 2025). In contrast, SOAR analysis shifts the focus toward strengths and opportunities but may overlook critical weaknesses or operational inefficiencies (Karadzhov, 2026).

NOISE analysis attempts to address these limitations by combining elements of both problem-oriented and opportunity-driven approaches. It incorporates the identification of organizational needs and areas for improvement while simultaneously recognizing strengths, opportunities, and exceptional practices. This dual orientation enhances its applicability in complex and rapidly changing environments, where both risks and potentials must be considered simultaneously.

From a theoretical perspective, NOISE analysis aligns with principles of systems thinking and continuous improvement, emphasizing feedback loops, adaptive learning, and iterative refinement of strategies (Senge, 2006; Deming, 1986). It also reflects elements of appreciative inquiry by acknowledging successful practices (exceptions) and leveraging them as a basis for future development.

Core Components of NOISE Analysis

Each component of the NOISE framework represents a distinct analytical dimension, contributing to a comprehensive understanding of organizational or systemic conditions.

Needs (N)

The “Needs” dimension focuses on identifying gaps, deficiencies, and unmet requirements within the analyzed system. These may include resource shortages, structural inefficiencies, skill gaps, or unmet stakeholder expectations. Unlike weaknesses in SWOT analysis, which are often broadly defined, “Needs” emphasize **actionable deficiencies**, directly linked to potential interventions.

Opportunities (O)

Opportunities represent external or internal conditions that can be leveraged to achieve strategic advantages. These may include market trends, technological advancements, policy changes, or emerging consumer demands. In contrast to traditional frameworks, NOISE analysis encourages the explicit connection between opportunities and identified needs, facilitating more targeted strategic responses.

Improvements (I)

The “Improvements” dimension is one of the most distinctive elements of NOISE analysis. It focuses on **specific, actionable measures** aimed at enhancing performance, efficiency, or competitiveness. While SWOT analysis often stops at identification, NOISE explicitly incorporates the transition from diagnosis to action by requiring the formulation of improvement strategies (Kotter, 1996).

Strengths (S)

Strengths refer to existing capabilities, resources, or advantages that provide a competitive edge. These may include organizational competencies, technological infrastructure, brand reputation, or human capital. In line with contemporary strategic management approaches, strengths are not only identified but also evaluated in terms of their potential to support improvements and capitalize on opportunities (Barney, 1991).

Exceptions (E)

The "Exceptions" component represents unique or outstanding practices, successes, or cases where performance exceeds expectations. This dimension is inspired by appreciative inquiry and focuses on identifying **what works particularly well** within the system. By analyzing exceptions, organizations can replicate successful practices and integrate them into broader strategic frameworks (Cooperrider & Srivastva, 1987).

Distinctive Features of NOISE Analysis

Compared to traditional analytical frameworks, NOISE analysis exhibits several distinctive characteristics:

- **Integration of diagnosis and action** – Unlike SWOT or PESTEL, which often remain descriptive, NOISE explicitly incorporates improvement-oriented thinking.
- **Balanced perspective** – It simultaneously considers deficiencies (Needs), potentials (Opportunities), and existing capabilities (Strengths).
- **Focus on implementation** – The inclusion of "Improvements" ensures that analysis leads to concrete strategic measures.
- **Recognition of best practices** – The "Exceptions" dimension introduces a positive analytical lens, enabling the identification and replication of successful cases.

These features position NOISE analysis as a hybrid model that bridges the gap between traditional diagnostic tools and modern, action-oriented strategic frameworks.

Conceptual Comparison with Established Frameworks

A comparative perspective further clarifies the contribution of NOISE analysis within the broader analytical landscape.

- Compared to SWOT analysis, NOISE replaces the often passive identification of weaknesses with the more proactive concept of "Needs" and introduces a dedicated category for "Improvements," thereby enhancing practical applicability (Karadzhov, 2025).
- In relation to PESTEL analysis, NOISE operates at a more operational level, focusing not only on external factors but also on internal transformation processes.
- Compared to SOAR analysis, NOISE retains a more balanced perspective by incorporating both positive and corrective dimensions, avoiding an overly optimistic bias.

Through this integrative approach, NOISE analysis offers a more flexible and actionable framework, capable of addressing the limitations of existing models while maintaining conceptual clarity and usability.

The relationships between the core components of NOISE analysis can be conceptualized as an integrated and dynamic framework, as illustrated in Figure 1. The model highlights the interaction between needs, strengths, opportunities, improvements, and exceptions, emphasizing their role in supporting strategic decision-making.

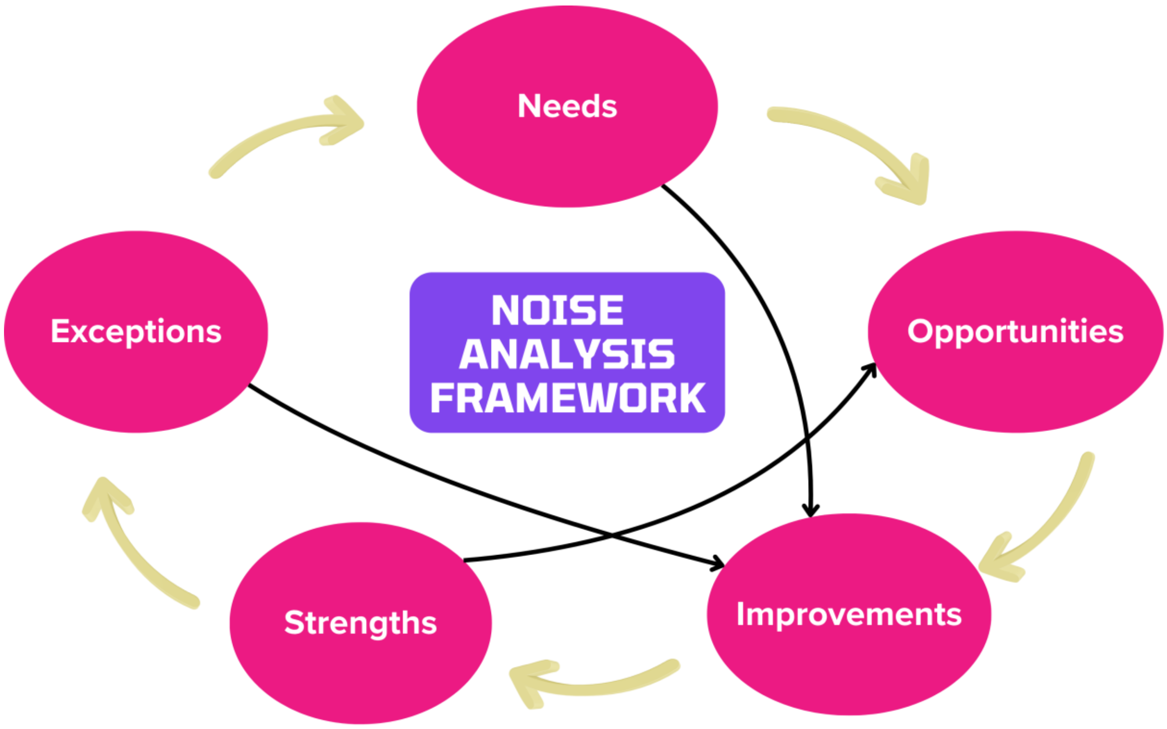

Figure 1. Integrated NOISE Analysis Framework. *Source: Author's own elaboration*

The integrated structure of NOISE analysis, as illustrated in Figure 1, highlights its capacity to combine diagnostic and action-oriented dimensions within a unified analytical framework. This conceptual foundation provides the basis for the development of a structured and replicable methodology for its practical application.

METHODOLOGY: HOW TO CREATE THE BEST NOISE ANALYSIS

The development of a standardized methodology for NOISE analysis is essential to ensure its consistent application across academic and practical contexts. While existing analytical frameworks often remain descriptive, the present study proposes a **structured, step-by-step approach** that transforms NOISE analysis into a replicable and actionable strategic tool.

General Principles of NOISE Analysis

The proposed methodology is based on several key principles:

- **Clarity and categorization** – Each factor must be clearly assigned to one of the five NOISE dimensions.
- **Actionability** – The analysis should lead directly to strategic decisions or improvement measures.
- **Balance** – Equal attention should be given to deficiencies, potentials, and strengths.
- **Systematic evaluation** – Factors should be assessed using consistent criteria.

These principles ensure that NOISE analysis moves beyond descriptive listing and becomes a **decision-support framework** (Porter, 1985; Bryson, 2018).

These principles ensure methodological consistency and enhance the analytical reliability of the NOISE framework across different application contexts.

Step-by-Step Procedure

The process of conducting a NOISE analysis can be structured into five main steps:

Step 1: Define the Scope of Analysis

The first step involves clearly defining:

- the system (organization, sector, destination, project)
- the objectives of the analysis
- the temporal and spatial scope

A well-defined scope ensures that the analysis remains focused and relevant.

Step 2: Data Collection and Factor Identification

Relevant data should be collected from:

- statistical sources
- policy documents
- expert interviews
- field observations

Based on this information, key factors are identified and preliminarily grouped into the five NOISE categories (Yin, 2018).

Step 3: Classification into NOISE Categories

All identified factors are systematically categorized as:

- **Needs (N)** – critical gaps and deficiencies
- **Opportunities (O)** – favorable external or internal conditions
- **Improvements (I)** – actionable measures and interventions
- **Strengths (S)** – existing advantages and capacities
- **Exceptions (E)** – best practices or outstanding performances

This classification stage is crucial, as it determines the analytical structure of the model. This structured classification facilitates a comprehensive and balanced assessment of both internal and external factors.

Step 4: Evaluation and Prioritization

To enhance analytical rigor, each factor can be evaluated using a **scoring system** (Saaty, 1980), for example:

- Importance (1–5)
- Urgency (1–5)

- Feasibility (1–5)

A composite score can then be calculated to prioritize actions:

$$Score = \frac{Importance + Urgency + Feasibility}{3}$$

This allows:

- ranking of factors
- identification of high-priority interventions
- objective comparison between elements

Step 5: Strategy Formulation

The final step involves transforming the analysis into **strategic actions**, including:

- addressing critical needs through targeted improvements
- leveraging strengths to exploit opportunities
- replicating successful exceptions
- integrating all elements into a coherent strategy

This step distinguishes NOISE analysis from traditional frameworks by ensuring a direct transition from diagnosis to implementation.

This stage ensures that the analytical process results in coherent and actionable strategies, directly linking evaluation outcomes to implementation.

Figure 2. Step-by-Step Process of NOISE Analysis. *Source: Author's own elaboration*

The process of conducting a NOISE analysis can be structured into five main steps, as illustrated in Figure 2. The proposed sequence ensures a logical progression from problem identification to strategy formulation, enhancing both clarity and practical applicability.

NOISE Matrix Model

The results of the analysis can be organized into a structured matrix (Figure 3).

Figure 3. NOISE Analysis Matrix (Conceptual Representation). *Source: Author's own elaboration*

The visual representation of the NOISE matrix, as shown in Figure 3, provides a structured overview of its core analytical components and their practical interpretation. Building on this structure, the following section presents the integrated conceptual model that explains the relationships between these elements.

Integrated NOISE Model (Conceptual Framework)

The proposed methodology conceptualizes NOISE analysis as an integrated system, where relationships between categories are essential:

Needs → addressed by → **Improvements**

Strengths → used to exploit → **Opportunities**

Exceptions → inform → **Improvements and strategies**

Advantages of the Proposed Methodology

The standardized NOISE methodology offers several advantages:

Operational clarity – clear steps and structure

Strategic orientation – direct link to decision-making

Flexibility – applicable across sectors

Quantification potential – allows scoring and prioritization

Replicability – suitable for academic research

EXAMPLE APPLICATION OF NOISE ANALYSIS IN HIGHER EDUCATION

To further demonstrate the applicability of the proposed methodology, this section presents a realistic application of NOISE analysis in the context of a higher education institution undergoing organizational and digital transformation (Altbach et al., 2019). The example reflects common challenges faced by public universities in Southeast Europe and beyond, including increasing competition, digitalization pressures, and the need for improved efficiency and student satisfaction (Selwyn, 2016).

Context of the Analysis

The analyzed case concerns a **public university in transition**, aiming to modernize its administrative processes, enhance the quality of education, and expand its digital infrastructure. The institution faces growing expectations from students, accreditation bodies, and international partners, while operating under resource constraints and structural limitations.

The primary objective of the analysis is to identify key strategic factors and formulate actionable measures to support institutional development.

Identification and Classification of Factors

Based on commonly observed patterns in higher education systems, the following factors are identified and classified within the NOISE framework:

Needs (N)

- Limited digitalization of administrative and academic processes
- Insufficient integration of e-learning platforms
- Gaps in staff digital competencies
- Bureaucratic procedures leading to delays in decision-making processes

Opportunities (O)

- Availability of European funding for digital transformation
- Growing demand for online and hybrid education
- Opportunities for international academic partnerships
- Rapid development of educational technologies

Improvements (I)

- Implementation of integrated digital learning management systems
- Development of staff training programs in digital competencies
- Optimization of administrative procedures
- Strengthening international collaboration initiatives

Strengths (S)

- Qualified academic staff with strong disciplinary expertise
- Established institutional reputation
- Existing research capacity and academic networks

- Diverse study programs

Exceptions (E)

- Successfully implemented online courses in specific faculties
- High-performing departments with efficient management practices
- Positive student feedback in selected programs
- Effective use of digital tools in isolated cases

This classification reflects typical structural and strategic challenges observed in higher education institutions undergoing digital transformation.

Evaluation and Prioritization

The identified factors are evaluated using the proposed scoring system (importance, urgency, feasibility). A simplified example is presented in Table 2.

Table 2. Example of NOISE Factor Evaluation in Higher Education

Factor	Category	Importance	Urgency	Feasibility	Score
Digitalization gap	Needs	5	5	4	4.67
E-learning implementation	Improvements	5	5	4	4.67
EU funding opportunities	Opportunities	4	4	5	4.33
Academic staff expertise	Strengths	4	3	5	4.00
Successful online courses	Exceptions	4	4	4	4.00

The evaluation highlights **digital transformation and capacity building** as priority areas requiring immediate strategic attention.

Strategy Formulation

Based on the NOISE analysis, several strategic directions can be formulated:

- **Addressing Needs through Improvements**
  → Introduce integrated digital platforms for administration and teaching
  → Develop structured training programs for academic and administrative staff
- **Leveraging Strengths to Exploit Opportunities**
  → Utilize existing academic expertise to expand online and hybrid programs
  → Strengthen participation in international research and education networks
- **Scaling Exceptions into Institutional Practices**
  → Replicate successful digital teaching models across faculties
  → Adopt best-performing administrative practices at institutional level

Interpretation of Results

The application of NOISE analysis in the higher education context demonstrates its capacity to:

- bridge the gap between **diagnosis and implementation**
- integrate **structural challenges and innovation potential**
- support **evidence-based strategic planning**

In contrast to traditional analytical frameworks, which often remain descriptive, the NOISE approach facilitates the direct transformation of identified factors into targeted actions. This makes it particularly suitable for institutions undergoing complex transitions, such as universities adapting to digital and organizational change.

DISCUSSION

The results of the proposed framework and its illustrative application highlight the growing need for more integrated, action-oriented strategic analysis tools in contemporary management and organizational research (Grant, 2016). While traditional frameworks such as SWOT, PESTEL, and SOAR continue to play a central role in strategic analysis, their limitations create space for the development of alternative models such as NOISE analysis.

Comparative Advantages of NOISE Analysis

One of the key contributions of NOISE analysis lies in its ability to bridge the gap between diagnosis and implementation. Traditional frameworks, particularly SWOT analysis, are often criticized for producing descriptive lists of factors without providing clear guidance on how these factors should be translated into strategic actions (Karadzhov, 2025). In contrast, the explicit inclusion of the “Improvements” dimension in NOISE analysis ensures that the analytical process is directly linked to actionable outcomes.

Similarly, while PESTEL analysis offers a comprehensive overview of macro-environmental influences, it remains largely external and does not inherently address internal transformation processes or operational improvements (Karadzhov & Patarchanova, 2025). NOISE analysis complements this limitation by integrating both internal and external perspectives within a unified framework.

Compared to SOAR analysis, which emphasizes strengths and opportunities, NOISE analysis provides a more balanced approach by incorporating both positive and corrective dimensions. The inclusion of “Needs” and “Improvements” ensures that critical deficiencies are not overlooked, while “Exceptions” introduce a mechanism for identifying and replicating best practices. This combination enhances the analytical depth and practical relevance of the model (Karadzhov, 2026).

Another important advantage is the dynamic nature of NOISE analysis. Unlike static frameworks, NOISE encourages iterative evaluation and continuous refinement, aligning with modern approaches to strategic management and organizational learning (Senge, 2006).

Practical Implications

The proposed NOISE framework has broad applicability across multiple domains, including:

- business management and organizational development
- higher education and institutional transformation
- tourism and regional development

- public administration and policy analysis

Its structured methodology, combined with the possibility for quantification and prioritization, makes it particularly useful for:

- decision-makers seeking actionable insights
- researchers conducting applied studies
- practitioners involved in strategic planning

Furthermore, the integration of "Exceptions" as a distinct analytical dimension provides a valuable tool for identifying successful practices and scaling them across organizations. This aligns with contemporary trends in knowledge management and innovation diffusion.

Theoretical Contributions

From a theoretical perspective, this study contributes to the field of strategic management by:

- introducing a **standardized methodological framework for NOISE analysis**
- expanding the conceptual landscape of strategic analytical tools
- integrating elements of diagnostic, appreciative, and action-oriented approaches

The proposed model can be positioned as a **hybrid analytical framework**, combining the strengths of traditional models while addressing their limitations. In doing so, it contributes to the ongoing evolution of strategic analysis methodologies in response to increasingly complex and dynamic environments.

Limitations of the Study

Despite its contributions, the present study has several limitations.

First, the proposed framework is primarily conceptual and methodological, supported by an illustrative application rather than an empirical case study based on primary data. While this approach ensures flexibility and generalizability, future research could benefit from applying NOISE analysis in specific organizational or sectoral contexts.

Second, the scoring system introduced in this study, although useful for prioritization, may involve a degree of subjectivity depending on the evaluator's perspective. Further research could explore the development of more advanced quantitative models or decision-support systems.

Third, the relatively limited presence of NOISE analysis in existing literature restricts the scope for extensive comparative validation. However, this limitation also represents an opportunity for future research and development.

Directions for Future Research

Future studies could expand the application and validation of NOISE analysis in several directions:

- empirical case studies across different sectors
- comparative analyses with other strategic frameworks
- integration with quantitative decision-making models
- application in emerging fields such as digital transformation and sustainability

Additionally, the development of visual models, software tools, and decision-support systems based on NOISE analysis could further enhance its practical applicability and academic impact.

CONCLUSION

This study set out to develop a standardized and practical framework for conducting NOISE analysis, addressing the existing gap in the literature related to the lack of structured methodologies for this underutilized analytical approach. By systematizing the key components of NOISE – Needs, Opportunities, Improvements, Strengths, and Exceptions – and integrating them into a coherent step-by-step process, the paper contributes to both the theoretical and practical advancement of strategic analysis.

The findings demonstrate that NOISE analysis offers a flexible, balanced, and action-oriented alternative to traditional frameworks such as SWOT, PESTEL, and SOAR. Its ability to simultaneously incorporate diagnostic elements, improvement-oriented thinking, and the identification of best practices positions it as a hybrid model capable of addressing the complexities of contemporary organizational environments.

A key strength of the proposed framework lies in its emphasis on implementation and decision-making. By explicitly including the "Improvements" dimension and introducing a structured evaluation and prioritization mechanism, NOISE analysis moves beyond descriptive assessment and supports the formulation of concrete strategic actions. Additionally, the inclusion of "Exceptions" enhances the analytical depth by enabling the identification and replication of successful practices.

The illustrative application in the context of higher education further confirms the practical applicability and adaptability of the model across different sectors. Its generic structure allows for broad use in business, public administration, tourism, and institutional development, making it a versatile tool for both researchers and practitioners.

In conclusion, the proposed NOISE framework contributes to the ongoing evolution of strategic analysis methodologies by offering a clear, structured, and replicable approach that bridges the gap between analysis and action. Given its flexibility and potential for further development, NOISE analysis represents a promising direction for future research and application in strategic management and related fields.

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Contemporary Challenges and Future Opportunities of Railway Transport in the Local Development of Mountainous and Rural Regions in Bulgaria

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ABSTRACT

In the spatial and regional development of the territory, railway transport is of crucial importance, dictated by its indisputable advantages such as reliability and regularity. These characteristics are the basis of the security and the predominantly social nature of the transport of passengers from various professions and groups of society. This essential role of railway transport is vitally important, especially in territories with significant spatial limitations of the geographical environment, such as the mountainous and rural regions. In many cases, this transport not only provides spatial accessibility but is the basis of the normal functioning of the entire complex of social and economic activities. The role of mountain railway transport continues to be upgraded with new technical solutions that allow the development of specialized economic functionalities, fully utilizing the resources of these spaces.

In the national space of the Republic of Bulgaria, railway transport began to play a more significant role already at the end of the 19th century. Its importance for exploiting the national territory in the last century formed the backbone of the economy, gradually outlining its industrial profile. In its development, the spatial focus is predominantly on the plain-lowland and river valley territories. The evolution of railway transport in the mountainous areas mostly plays a transit role. In addition, there are also mountainous areas where rail transport has an organizing role to a much greater extent.

The Rhodope mountain massif, with its significant spatial extent, specific geological structure, and geomorphological development, generates serious infrastructural interest in the territory. The historical dynamics of the geopolitical processes within this border mountain Rhodope, the significant demographic potential that has formed, and its settlement and economic development are, in no small

measure, the result and the role of the few railway lines that continue to exist. An essential role is played by the so-called "Rhodope Narrow Gauge Railway," which tops the Guardian readers' 2020 ranking of the top 10 best scenic railway journeys in Europe.
The article is devoted to the stages in this railway line's creation, development, and use. The analysis includes demographic, settlement, and economic assessments of the infrastructural impact in the various territorial communities within its spatial scope today, as well as the prospects for its future development and use.

Keywords: *Railway transport, Mountainous regions, Rural regions, Local development, Narrow-gauge railway*

INTRODUCTION

The natural geographical isolation of mountain areas from regional, national, and international infrastructure networks is a decisive limiting factor in the local development of the settlements and territorial communities. As a result, the domestic markets of the already limited resources available to these territories and the few products their local economies produce remain outside the circulation of national and global economic processes. Even in cases where upland areas are becoming a raw material appendage of farms in lowland and lowland areas, it is necessary to provide them with adequate transport and technical infrastructure systems.

With the advent of industrialization, the need to move goods in large quantities, and the development of modern means of transport such as railways and roads, mountains are increasingly being incorporated into networks for access, transit, and communication. Questions surrounding these developments centre on the impact of these increased accessibilities, which are a global phenomenon, and whether they positively or negatively impact the sustainable development of mountains [1].

Along with the infrastructural and, in particular, transport modernization of these territories in the initial stage of their economic activation, several forms of classical transport activities that contribute to preserving the local cultural landscape remain. This makes them an essential part of the resources for developing several specialized forms of tourism that contribute to the revitalization of the economy of mountain areas and their sustainable local development.

Narrow gauge railways are a small part of the overall network in individual countries. Even in a country like India, where this mode of transport has a 170-year history, and Indian Railways is today the most significant public sector undertaking in the country [2], its relative share in the total length of the rail network is only 2.4%. Nevertheless, they still play a crucial role in transport services for the population and economy in the hill areas.

There are also not a few cases where a significant part of the narrow gauge railway network has lost, in whole or in part, its service infrastructure importance, and many lines on it have been closed and even dismantled. In contrast, others have been expanded into normal ones. There are many examples of this situation in the development of the Bulgarian narrow-gauge railway network:

- The first narrow-gauge railway in Bulgaria was opened 107 years ago - in 1916 on the line from Radomir to Dupnitsa (600 mm gauge and 44.5 km long), was part of a route to the then village of. Valovishta (today in Greek territory - town of Sidirokastro, in the Turkish period Demirhisar). The idea was to take the line to the Aegean Sea, which the Bulgarian people aptly named "White Sea," a name that is still used today in the colloquial language as a symbol of warmth and beauty;

- The line Ahtopol - Brodilovo - Kosti (600 mm and 33 km) was opened in 1949 and existed for seven years, after which it was closed and dismantled, but the route was preserved and can be used in its eventual restoration;

- General Todorov - Petrich - Zlatarevo (600 mm and 31 km) was opened in 1917 and extended to Petrich in 1969, and the rest to Zlatarevo in 1920 after the Treaty of Neuilly-sur-Seine was closed and dismantled;

- Burgas - Pomorie (600 mm - 22 km) was opened in 1925, expanded to normal and with a changed route in 1930, closed for passenger traffic in 2002, dismantled section Pomorie - Vinprom Pomorie 2004, dismantled section Vinprom Pomorie - mines Cherno More 2010;

- Varvara - Pazardzhik (760 mm and 16 km) was opened in 1928, closed in 2002 and dismantled;

- Dolni Chiflik - Solnik - Dyulino (600 mm) was opened in 1921, handed over in 1923 to the Ticha Forestry, and closed and dismantled after 1959. In connection with its extension, a part of the tunnel was dug under the Eastern Balkan Mountains to build a connection with the standard line to Pomorie. A German delegation from Brandenburg has expressed interest in restoring the forest railway as a tourist attraction.

- Dupnitsa - Bobov dol - 600 mm was opened in 1917, expanded to normal in 1950, and the two narrow gauge steam locomotives were handed over for operation on the line Akhtopol - Brodilovo - Kosti;

- Kazanlak - Arsenal JSC (600 mm) was opened in 1927 for internal factory transport but was closed and dismantled.

- Kazichene - Vrana Palace is known as the Royal Narrow Gauge Railway (600 mm and 5.5 km). It was opened between 1906 and 1911 and operated as a steam line until the middle of the century. The line is a freight and passenger line, and it connects the Royal Station at the village of Kazichane with the Vrana Palace for the needs of the monarch and the official guests of the King and his family. There are traces of the track until around 1960 behind the Royal Station to the entrance switches on the Sofia side and at the Kazichene station. The following travelled on it: the British King George V, the Emperor of Austria-Hungary Charles I of Austria, the Italian Queen Helena, the Serbian King Alexander just two weeks before he was assassinated by the Internal Macedonian Revolutionary Organization (IMRO) in Marseilles, the Romanian King Carol II, the Ottoman Crown Prince Şehzade Yusuf Izzeddin, the Grand Duke Alexander Mihailovich (son of the Tsar-Liberator Alexander II) and many other famous personalities.

- Kaspichan - Krayina, today, the village of Todor Ikonomovo (600 mm and 72.8 km) was opened in 1917. Serbian prisoners of war participated in the construction, but it was closed later in 1964;

- Kostinbrod - Pozharevo (600 mm and 11 km) was opened in 1917, and in 1920, it was handed over to the Izida factory, later closed and dismantled.

- Kocherinovo - Kula (Bricebor) - Rila Monastery - Kirilova Polyana (600 mm and 37.5 km), known as the Rila Railway, was opened in 1918, and from 1923, included in the Bulgarian State Railways (BDZ), closed in 1960 and dismantled;

- Kula (Bricebor) - Radovitsa (600 mm and 7.25 km) was opened in 1946 as a branch of the main line of the Rila Railway, closed and dismantled in 1960;

- Plachkovtsi - Prince Boris Mine, today the village of Grubchevo (600 mm and 5 km), was opened in 1901. In 1947, the BDZ handed it over as the property of Grubchevo Mine, closed and dismantled in the 1950s, but there are interests in restoring it as an attraction;

- Rakovski (now a quarter of Dimitrovgrad city) - Maritsa mine (600 mm) was opened in 1917 and closed in 1938;

- Rakovski (now a quarter of Dimitrovgrad city) - Haskovo (600 mm and 21 km) was opened in 1922 and expanded to normal in 1928;

- The Tran narrow gauge railway that serves the Zlata mine (600 mm and 40 km) has a history of several decades. Construction began in 1915, but the section of the route with the completed 300 m tunnel at the river's gorge. The 300 m-long tunnel remained unfinished after the Treaty of Neuilly-sur-Seine. The 12 km section Dragoman - Yalbotina (at the coal mine Beli breg), which is now closed and dismantled, and the 28 km section Rakita, Zvontsi, Zvonska Banya, Transki Odorovtsi, Bobovishte, Erma, Poganovski Monastery, Vlasi, Komiye, Gorna Darzhina, Sukovo, Belo Pole were built. The miners call the train "Tsira". By 1942, two smaller tunnels were made to the village of Petachintsi to connect the sections, but again, the western outskirts were taken away. The Tsira section was closed together with the mine in 1963. In 1981, the latter's track was asphalted and converted to a convenient road due to the miniature railway gradients.

- Cherven Bryag – Oryahovo (760 mm and 102 km) opened in 1918.

Construction started from Cherven Bryag on 10 September 1917; on 28 February 1918, the section to Knezha was opened for operation, and on 15 July - to Byala Slatina. The construction of the Byala Slatina - Oryahovo section began in early 1922, and by November 1925, it was completed to the bank of the Danube River near the village of Saraevo. It connected with the main railway line to Northern Bulgaria on the Sofia - Ruse route, today part of the main line No. 2 Sofia - Kaspichan - Varna. The line was closed in 2002 and then dismantled.

- The Chukurovo Mine - terminal station (600 mm and 2 km) was opened in 1917 as a rope line and handed over to the mines for use.

- The Lower Yundola Forestry (600 mm and 5 km) was opened in 1917, handed over to the Yundola Forestry in 1921, and subsequently closed and dismantled.

- Yambol - Elhovo (600 mm) was opened in 1917 on a horse-drawn railway, widened to normal and with a changed route in 1930, and closed in 2002, but still needs to be dismantled.

Today, two narrow gauge railways of concise length are used in urban settings and have attraction functions:

- Kardzhali - The Children's Railway "Pioneer" (600 mm and 1.21 km) was opened in 1962, located in the park "Recreation and Culture" above the Druzhba Stadium, and operates as an attraction;

- The Pioneer Plovdiv Railway (600 mm and 1.1 km) was opened in 1979 but closed in 1997 and reopened in 2007 as an operating attraction [3].

The conclusions that can be drawn from the above information are that narrow-gauge rail transport occupied an essential place in the initial period of establishing and developing the national railway network in Bulgaria. With the spatial extension of their geography beyond the mountainous areas where they are the most suitable and efficient transport, narrow gauge railways have become extremely important for several plain, lowland, and valley areas. To extract mineral resources in these areas, they provide the basic infrastructure and the bulk of the transport service for the leading economic activities. Their role as the territorial basis for future regular railway routes along some of the primary spatial axes in the country is also vital. The closure of the vast majority of narrow gauge railways creates many social and economic challenges in their predominantly rural and extractive areas, which underpins the subsequent depopulation processes that are intensifying.

MATERIALS & METHODS

This study employs a diverse methodological framework based on general and specialized research approaches. Several scientific publications, including analytical research materials, archival, normative, strategic, and planning documents described in both domestic and international literature, were examined. The opinions and interpretations of various authors and institutions regarding the key issues related to the research topic were analysed. Based on various scientific approaches, including spatial (horological) and historical (chronological) approaches, as well as geographical analysis, comparative analysis, synthesis, and other research methods, the authors present their interpretations and conclusions on the issues examined in this study.

The data used in the mapping part is derived from two primary sources: the Japan International Cooperation Agency (JICA) project and the National Statistical Institute of Bulgaria, supplemented with data from the Population Data Registry (GD "GRAO"). The JICA project provides critical data on Bulgaria's railway network, essential for creating precise and up-to-date maps. This data includes railway routes, station locations, and associated infrastructure details. Population data from the National Statistical Institute of Bulgaria and GD "GRAO" were used for population density analysis.

These datasets provide valuable insights into the spatial distribution of the population across different regions, including urban and rural areas, as well as demographic characteristics. Population data from the 2021 National Census (NSI) were supplemented with the 2023 Population Data Registry (GD "GRAO"), providing the most up-to-date demographic information available for the study. The authors' maps were produced using ArcMap 10.2.2, a component of the ArcGIS suite. This GIS software application is widely recognized for its advanced geospatial analysis capabilities and cartographic functions. It played a pivotal role in the execution of the present study, serving as the primary tool for creating maps of Bulgaria's railway network and conducting population density assessments within the study area surrounding the narrow-gauge railway.

RESULTS AND DISCUSSION

Spatial, geopolitical, historical, economic and social preconditions

During the First World War, Bulgaria felt a massive lack of fast transport links to the country's peripheral regions. Many Bulgarian lands were almost cut off, making them easy targets for belligerent states eager for new territories. The problem was especially severe in the Rhodope Mountains, the most inaccessible and almost unconnected territory of the national space.

In order to deal with this severe transport problem, in 1915, the government ordered the exploration of the valleys of the Yadenitsa, Eli Dere (today Chepinska River), and Vucha River and to choose where to lay the railway to the Rhodope Mountains. In the following 1916, it was decided to build a narrow gauge railway from Saranbey station through the gorge of the Eli Dere River, the Chepinska riverbed, the Avram saddle, and from there along the Mesta River valley to Razlog and Nevrokop (today's Gotse Delchev). On May 25, 1920, the 19th Ordinary National Assembly voted and passed Law No. 1257 for the construction of a narrow-gauge 760-mile railway line from Saranbey station (today Septemvri) to the village of Lazhene (today a district of Velingrad), Yakoruda, Razlog and Nevrokop.

The question immediately arises: Who will design the line? The first two engineers invited refused instantly and resigned because of the extremely dangerous and wild Elli Dere. Then, the young engineer Stoyan Mitov, who had just graduated from Germany, came home to Bulgaria and was assigned to start designing the route of the narrow railway line from the Thracian lowland to the Razlog valley.

Work started in 1920, but due to the onset of winter, actual activity was postponed until spring. So in 1921, workers from the labor conscription formed just then from the office of Alexander Stamboliiski and headed by engineer Mitov began hard work on the first flat section between Saranbey station and the village of Varvara. In 5 years - by the summer of 1926, the line broke through the gorge and reached the village of Lazhene. The work was carried out in harsh conditions without equipment or mechanization. The ten tunnels in this section were drilled with stone blasts, picks, and shovels, extremely dangerous for the workers' lives.

The first train in narrow gauge history departed on August 2, 1926, promptly at 11 o'clock. From Saranbey station, through Varvara station, Banite station, Dorkovo station, Bakardzhiyski Khan Station, Dolene station, Drenov Dol station, and Chukata station to the last station, Lazhene-Kamenitsa, the journey lasted 3 hours and 22 minutes. In 1927, the following section was opened between the villages of Lazhene and Chepino-Banya, today districts of Velingrad. With the opening a year later of the section from the village of Varvara to the town of Tatar Pazardzhik, the name of the line was changed by law, and it was called "Tatar Pazardzhik - Nevrokop," with a branch "Varvara - Saranbey." The law stated that the main starting and terminus station for trains on the line would be Pazardzhik.

Only in 1937, nine years later, the next section was put into operation - from Chepino-Banya to Yakoruda station. It was the most difficult to implement. Here - between St. Petka station and Avramovo station, the railway line climbs five floors, winding under itself through 16 tunnels in just 9 kilometers. We call this facility, unique in the world at this time, the "figure eight" because of the shape it makes when viewed from above. After Avramovo station, the line makes two spiral descents, also called "sixes" - covered and open. Thus, it reaches the station Cherna Mesta, and from there, it descends to Yakoruda along the valley of the Mesta River. The section was put into operation but needed an official opening. What is unique about the section from Velingrad to Avramovo is that here, the railway line Septemvri - Dobrinishte remains to this day the only means of transport for hundreds of locals from the high mountain villages near Tsvetino station, some of which do not even have a permanently surfaced road. Many of the local population there earn their living thanks to the narrow gauge railway, which remains vital for this mountain region today.

On July 30, 1939, the section to Belitsa station was opened, bringing the total length of the line from Septemvri to 101 kilometers. Then, the ceremonial ruler of Bulgaria - Tsar Boris III himself, drove the festive train. This event remains a lasting memory in the lives and minds of the local population as the two wonders - king and train in one.

For the next four years, the section Belitsa - Razlog - Bansko opened on March 3, 1943. This way, the biggest inner Rhodope valley - the Chepinska Valley - was connected with the Razlog valley, between the three mountains Rhodope, Rila, and Pirin, the last two of which are the highest in the country. Connecting these areas has another important additional demographic and social significance. It stems from the fact that at the very beginning of the 20th century, after the failed uprisings for independence, many families from this part of Bulgaria were displaced from the valley of the Rila River. Places in the Chepino riverbed - today's town of Velingrad. With the extension of the railway, natural conditions were created to continue the forcibly severed kinship, settlement, cultural, and economic ties between the populations of these geographically heavily settled mountain areas.

On December 9, 1945, the 6-kilometre section from Bansko to Dobrinishte station was put into regular operation. Unfortunately, it remains the last to this day. More than 78 years later, the line still has not reached its intended endpoint - today's town of Dobrinishte, Gotse Delchev.

The construction of this grand railway project involved mainly soldiers from the so-called labor conscription - local non-disabled Bulgarians who served the state in constructing extensive facilities in their respective regions of the country. The Bansko - Dobrinishte section was built with the voluntary labor of the inhabitants of the then village of Dobrinishte, today a town with dynamically developing tourist functions.

In the end, all the work on the design and construction of the line was done by Bulgarian engineers and workers, and the money for its construction came from state loans. The desire of the people of this mountainous region was significant and even leading in this process. Everyone understood and appreciated very well the importance of this highly difficult-to-implement infrastructure facility and how important the railway was for the settlement, demographic, and social stabilization of the mountain region, for its economic revitalization through the development of new industrial and tourist functions in many centers such as Velingrad, Yakoruda, Belitsa, Razlog, Bansko, Dobrinishte, etc.

Even though the narrow-gauge railway only reaches Dobrinishte, it has been the main transport for passengers and freight along the Mesta for almost half a century. Almost everything needed as raw materials for industry and not a small part of household goods was transported by narrow-gauge train to Dobrinishte and, in the south, freight trucks transported another 40 km to the town of Gotse Delchev. So, to a considerable extent, the "Narrow Gauge Railway - The Little Railway" also contributed to the development of the area of its planned terminus on the middle reaches of the Mesta River.

Modern geographical and technical characteristics

The railway line Septemvri - Dobrinishte (line No 16) is an integral part of the National Railway Network of the Republic of Bulgaria (Fig. 1).

In 2021, the national railway system in Bulgaria includes 4031 km, from which 995 km (24.7%) are doubled and 3001 km (74.4%) are electrified. Only one of the 28 districts in the country does not have a railway transport – Smolyan district.

It is the only narrow-gauge railway still operating in Bulgaria, with a 760 mm gauge, also known as Bosnian type gauge [4]. It is technically single and non-electrified, making it a typical mountain railway.

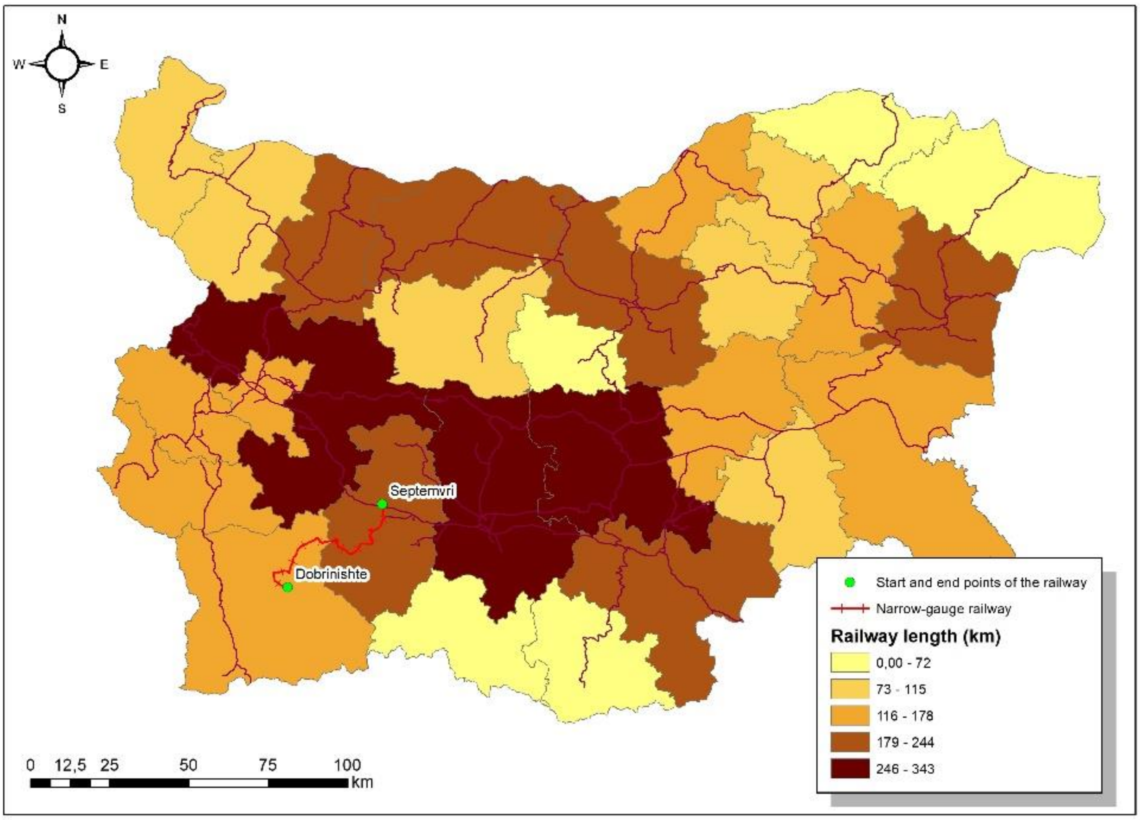

Fig. 1. Geographical map of the railway network in Bulgaria (prepared by the authors).

Its immense geographical importance is that it provides a vital link to some settlements in the Razlog Valley, the upper reaches of the Mesta River, the northern parts of the Western Rhodopes, and the valley of the Chepinska River with the Thracian Lowland.

The route of the railway line has a total length of 125 km and starts from Septemvri station at 238 m above sea level (altitude) see Fig. 2 and Fig. 3. It connects with the main railway line of the country - No. 1 (Sofia - Plovdiv - Nova Zagora - Yambol - Burgas) part of which is on the route of the international line Kalotina - Svilengrad, and on which the famous Orient Express train runs between Paris and Istanbul.

Initially, the route passes through flat terrain in the western part of the Upper Thracian Lowland, crossing at km 1,600 Republican Road I-8, formerly called "Tsarigradsko Shose." At km 4,600, there is also the first railway stop, "Pamporovo," at 271 m above sea level (on the Republican Road III-8402), which was renamed "Lazar Pamporov" on 13 December 2020 and opened in October 1993 for the needs of passenger train traffic to serve the population in the eastern part of the Varvara village.

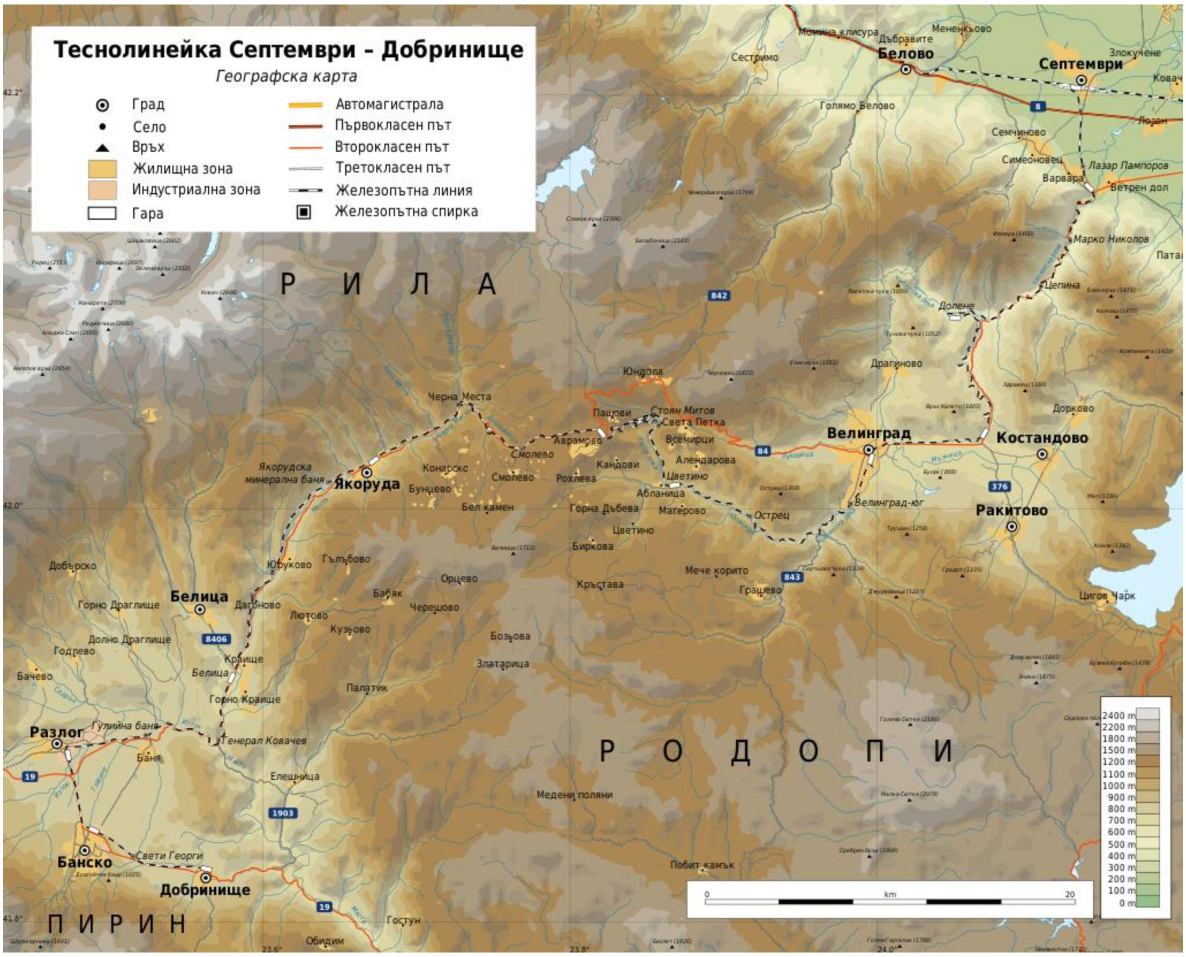

Fig. 2. Physical map of the territory near the narrow gauge railway. *Source*: [5]

The first railway station on the line is at km 5,750 in the village of. Varvara at 281 m above sea level. Via an iron railway bridge, the line crosses over the second-class Republican road II-84. It goes upstream along the Chepinska River, representing an orographic boundary between the Alabak and Karkaria Rhodope divisions. In this section, the line runs along the right bank of the river, reaching Varvarski Mineralni Bani (Mineralni Bani stop), which was later renamed Marko Nikolov, in honor of the railway cantonner who died in a rockslide while performing his duties. The stop serves the villages of Varvara and Vetren dol and is the starting point for the Ravno Bore hut.

The railway line passes at km 11,700 through the first and second railway tunnels, which follow each other immediately, 83 m long. 1928, during the Chirpan earthquake, a displacement occurred, and a new opening had to be dug in a southerly direction. The old one still exists and is next to the road, from which it can be seen and used in an emergency.

Immediately before the next railway stop on the route is tunnel No. 3, which in the early 1990s was merged with tunnels No. 4, 5, 6, 7, and 8 (with a total length of 78 m), at km 13,200 in order to protect the line from rockslides and landslides. The line then continued to Dorkovo railway station at km 13,875, which was renamed Tsepina railway station in 1928 (see Fig. 4). In 2003, the additional railway tracks were dismantled, the station building was closed, and it was converted into a railway station. It is the starting point for the fortress of Tsepina.

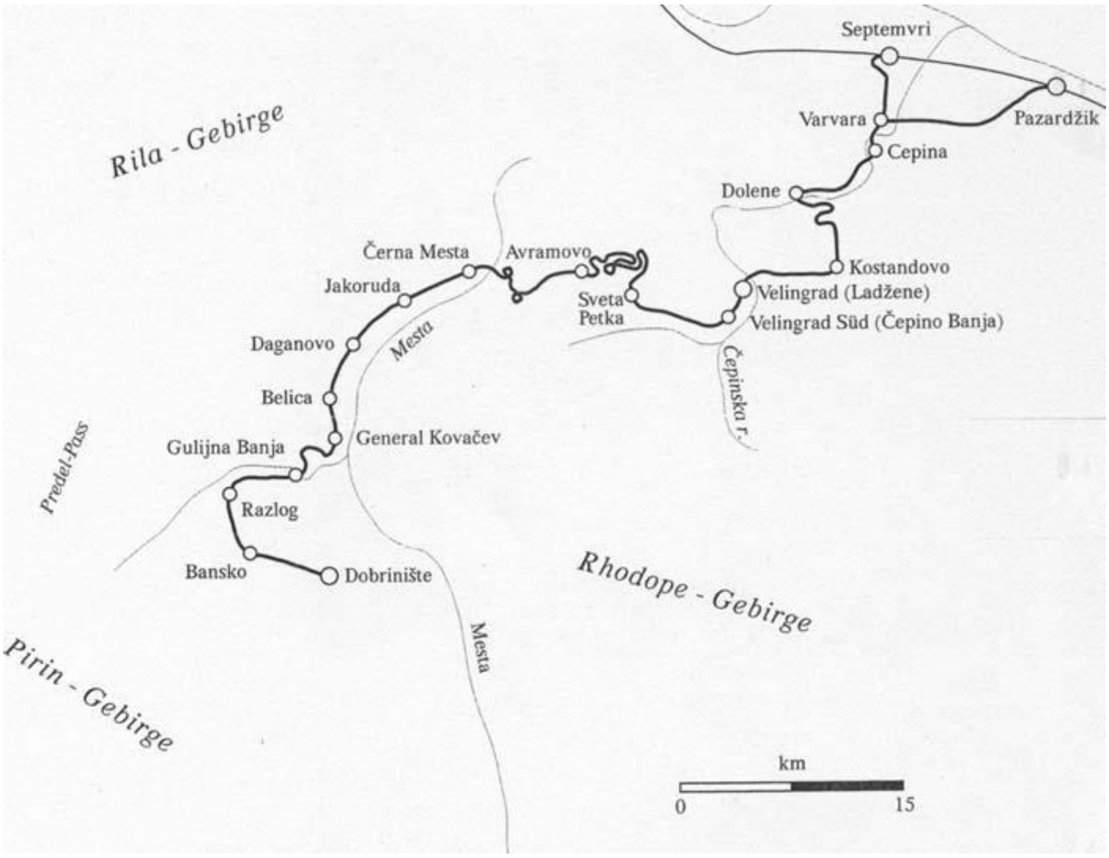

Fig. 3. Map of the route of the narrow-gauge railway Septemvri-Dobrinishte. *Source*: [6].

For six years now, the building of the former station has been transformed into the "Narrow Gauge Museum House," which was opened on 3 September 2017. The building was renovated and restored entirely with the voluntary work of over 20 people for two years. The museum aims to promote the centenary history of the narrow gauge railway and thus attract followers to the cause of preserving the last narrow gauge railway in the country. A rich collection of historical photographs tracing the entire history of the construction and operation of the Rhodope narrow gauge railway awaits you in the exhibition. There are photos of heavy construction works, lavish celebrations with the participation of the then monarch - Tsar Boris III, shots from the golden period of the line with the full trains, and the hard years of decay and destruction. Also displayed is an authentic timetable board from 1985, when 31 trains passed through the station a day. On the second floor, a hall dedicated entirely to the Pazardzhik narrow gauge railway - the Pazardzhik - Varvara line, closed in 2002. The former office of the Tsepina station has been restored as close as possible to its original appearance so that you can immerse yourself in the natural working environment of a railway manager of a time, mark a retro ticket on a composter as was once done, turn an actual railway switch and see many other exciting things that accompanied the narrow gauge railway during its existence.

Fig. 4. Train station of Tsepina. *Source*: [7].

After the Tsepina stop at km 14,800, there is the 74 m long tunnel No 9. At km 16,100, the line crosses the road to Velingrad, an iron railway bridge over the river passes on its left bank, and a cantonment with a permanent presence of a BDZ employee is built to service the barriers at the crossing. The next stop, Bakardzhiyski Khan at km 17,500, later renamed Milevi Skali, was closed in 2003. From here, the road and the line separated.

In order to gain length for the upcoming sizeable spatial gradient, the line continues along the left bank of the Chepinska River, passes through the short tunnel No. 10, then over an iron bridge over the river to reach Dolene station at km 20,520. The station is the starting point for the nearby Milevi Skali Peak, a historical site. For 10.9 km, the railway climbs 246 m above sea level on the West Rhodope Chukata hill, reaching the road again and continuing, but at a higher altitude, parallel to it. The railway reaches the Drenov Dol station at km 24,300, which has been opened and closed over the years [8], and in the 1970s, was opened as a two-track station to increase capacity but later closed again.

Entering the Chepinska valley, it reached the Chukata station, renamed on 20 September 1926 to Kostandovo station [9]. From the station, one can reach the towns of Rakitovo and Kostandovo by bus and the village of Dorkovo, where the Tsepina fortress and the Pliocene Park opened in 2013. The line gradually descends to the valley floor in this largest inland valley in terms of area. It runs parallel to the highway, crosses the Mutnitsa River via an iron bridge, and reaches the railway station of the village of Ludzene. It was renamed in 1948, becoming a district of the new town of Velingrad [10, 11, 12, 13] (see Fig. 5).

Fig. 5. Train station Velingrad - the largest town along the railroad.
Source: https://velingrad-bg.com/wp-content/uploads/2016/06/DSC_5001.jpg

In the section between Septemvri and Velingrad, the railway crosses the Chepinska River three times with iron bridges and passes through 10 tunnels totaling 380 m [14]. This section has a maximum gradient of 30‰ and a minimum radius of curves of 50 m. It is used in three places [9, 15]. The average gradient from Septemvri to Varvara is 3.9‰, from Varvara to Milevi Skali stop is 20‰, from Milevi Skali stop to Drenov Dol stop is 25.8‰, from Drenov Dol stop to Kostandovo station is 22.8‰ and from Kostandovo station to Velingrad is 9‰ [9].

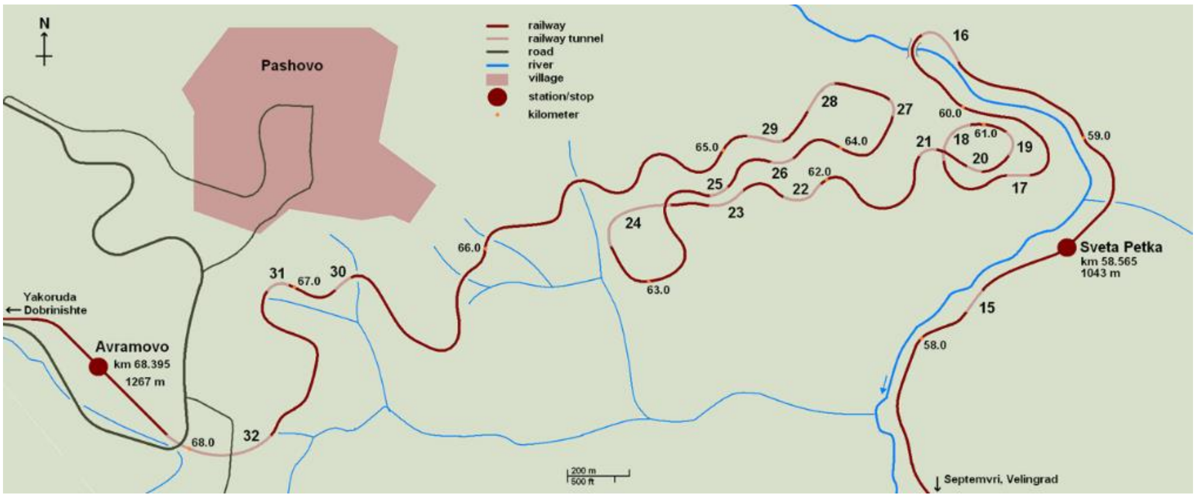

Fig. 6. The route between Sveta Petka station and Avramovo station. *Source*: https://upload.wikimedia.org/wikipedia/commons/a/a1/Sveta_petka-Avramovo_trackmap.png

The longest of them and the route of the whole line is tunnel No. 32, which passes under the Avram saddle. Its length is 314.3 m. Immediately after exiting it, at km 68,360, the line enters Avramovi Kolibi station, which was renamed Avramovo in 1983. The station is the highest on the Balkan Peninsula (see Fig. 7).

After the railway station, Velingrad South, located between str. Dimitar Blagoev and Str. Nikola Vaptsarov in Chepino neighborhood, the route continues along the left bank of the Ablanitsa River. It reaches the closed Bistritsa stop. It passes through tunnels No 11, 12, 13, and 14, which are 84 m long. The railway then reaches the Ostrets railway station, the starting point for Mount Ostrets. A Thracian sanctuary has been discovered in the western part of the peak. It can be reached along the "Path of Health."

The railway continued its ascent and reached the Yablanitsa station, later renamed Tsvetino. The line then runs along the right bank of the short Lyuta River. It passes through the 75 m long tunnel No. 15 and reaches the railway station St. Petka, located 1043 m above sea level. It serves the village of St. Petka and is the starting point for Yundola. After St. Petka station is Pashovo railway station, closed in 2003. On 13 December 2020, the Stoyan Mitov railway stop was opened, named after the prominent Bulgarian engineer.

Fig. 7. Avramovo station – the highest on the Balkan Peninsula. *Source*: https://upload.wikimedia.org/wikipedia/commons/2/2f/Avramovo_Railway_Station_2013_05.JPG

The next section of the route (Sveta Petka - Avramovo) is the most difficult in the construction of railways in the mountainous regions of the country (Fig. 6). Here was built the remarkable achievement of Bulgarian railway construction - a four-story artificial development, for a distance of 9.8 km, 224 m of altitude are overcome. The railway changes its direction six times. In this section, the railway line passes through 17 tunnels with a total length of over 2477.66 m.

It is located at 1267.4 m above sea level. It is the starting point for Veliitsa peak (1712 m). After Avramovo, the line descends along the valley of the Drushenitsa River, a Cherna Mesta River tributary. It reaches the stop Chisto Tepe, today Smolevo, which is the starting point for Veliitsa peak. There is also a deviation for Belmeken hut. The railway line runs along two artificial developments. The first is the so-called carousel, or covered six, formed by tunnels 33 and 34. The latter is 250 m long. The second is the so-called open six around the naturally formed mound at tunnel No 35, 59 m long, then reaches the Cherna Mesta stop. It is the starting point for the Belmeken Dam. The railway line runs along the right bank of the Mesta River. It crosses the Bela Mesta River and Gramada River.

The line then reaches the last station of this stage, Yakoruda. A paved road leads to the Treshchenik and Granchar huts and Musala Peak (2925 m) [10, 13]. Before the railway construction, there were no roads along this section. The total length of the route is 43.769 km, the maximum slope is 31.89‰, and the minimum radius of curves is 70 [15].

The railway line after Yakoruda continues to run along the right bank of the Mesta River, passes through the stops Yakorudska mineralna banya, Yurukovo, and Dagonovo, and reaches Belitsa station, which serves not only the town of Yakoruda but also the town of Belitsa. Belitsa also serves the high-mountain summer resort of Semkovo, as well as Dancing Bear Park [4, 6]. In this part, the line has a maximum slope of 15‰ and a minimum radius of curves of 80 m. During the laying of the line, 88 culverts and bridges were constructed [14].

Gradually, the line enters the Razlog valley. It reaches the General Kovachev station, which serves the village of Eleshnitsa and, in the past, was used for transporting uranium ore from the mine near the village. The route crosses the longest bridge (58.5 m) on the railway line. The next stop is Guliina Banya, which serves the developing spa and health resort. Banya. After another 5 km, the line reaches the town of Banya. Razlog, and after a short climb to the city of Banja, the largest ski center in the Balkans. Bansko. Both stations are the starting points for several sites of the two highest mountains in Bulgaria - Rila and Pirin (the huts Makedonija, Yavorov, Banderishka; some alpine lakes - Smradlivoto, Ribni, Bezbozhko; the peaks Vihren - 2914 m, Kutelo, Golyam Mechi Vrah, etc.). The maximum slope is 15‰, and the minimum radius of the curves is 540 m [14].

The last section is Bansko - Dobrinishte, with a length of 6.6 km. The station (see Fig. 8) serves the developing spa and ski resort of Bansko. Dobrinishte, the chalets Gotse Delchev and Bezbog, the Popovo, Bezbozhko, Tevno, Valiavishki, etc.

Rolling stock plays a very significant role in the functioning of the railway, which has been developing significantly over time, improving its technical capabilities (speed, power, safety, etc.), passenger comfort, and the variety of freight and passenger cars in the train sets.

Fig. 8. Dobrinishte station. *Source*: https://upload.wikimedia.org/wikipedia/commons/thumb/2/21/Dobrinishte_Railway_Station_16.JPG/1280px-Dobrinishte_Railway_Station_16.JPG

Fig. 9. Steam locomotive 1^{76}. *Source:* [19]

The first locomotives to be used on the narrow gauge line were the 1^{76} - 10^{76} series locomotives (see Fig. 9), the designation by small numerals after the series number indicating the gauge for which the locomotive was designed. They are two-cylinder, built to order for the General Directorate of Bulgarian State Railways in 1922 at the German factory Reinmetall - Düsseldorf. In 1923, the ten locomotives of the whole series were delivered. They were also used during the construction of the Saranbey - Ladzhene section.

During the period 1927-1939, steam locomotives of the 500^{76} series were used to serve passenger and freight traffic on the line (see Fig. 10). At the end of 1939, the delivery of the first five locomotives of the 600^{76} series was agreed.

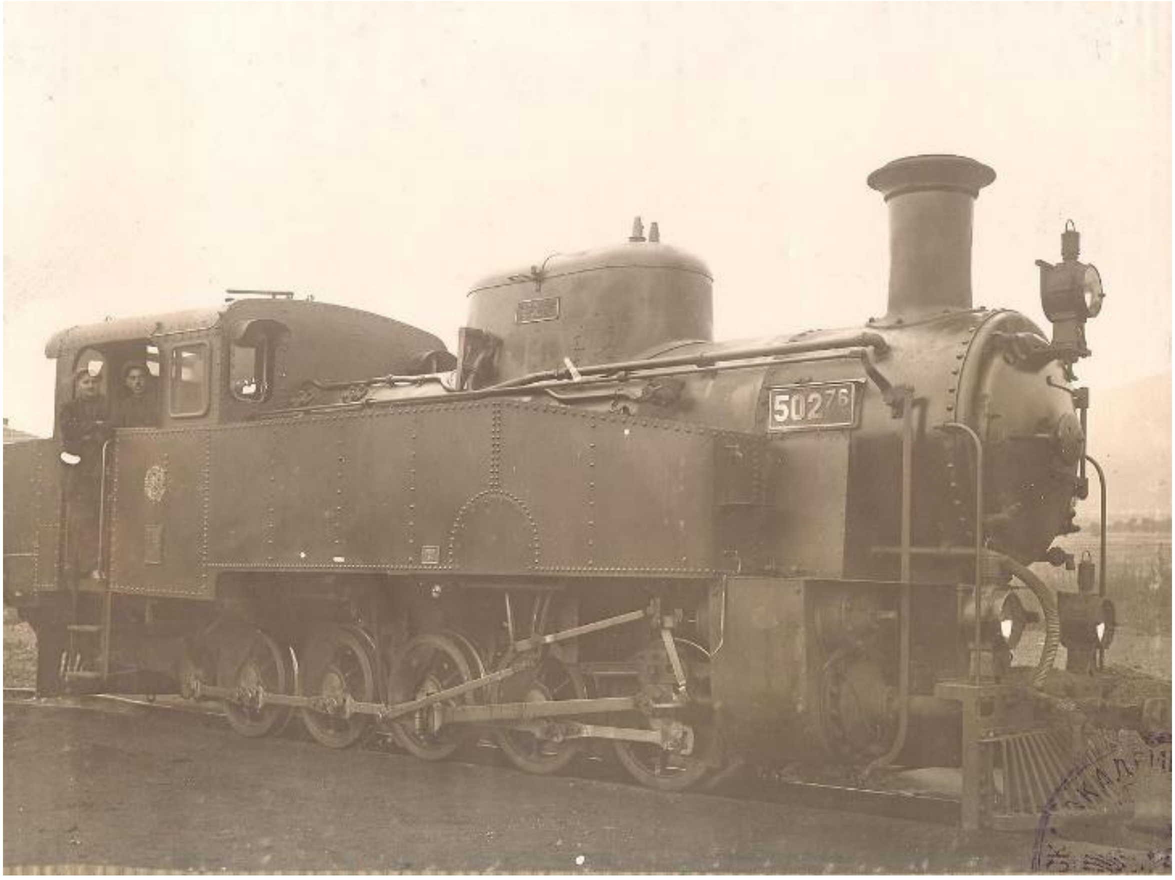

Fig. 10. Steam locomotive 502^{76}. *Source*: [20]

They were built in the German Schwarzkopf - Berlin factory. They were delivered in early 1941 and put into service the same year. They aimed to carry freight trains on narrow-gauge sections with large gradients and many curves in mountainous areas. In 1947, the following ten locomotives of the series were delivered from Poland. Their construction was carried out in "Pierwsza fabryka lokomotyw w Polsce" - Chrzanow.

They were put into service between the end of 1949 and the beginning of 1950. In 2004, one of the second series, 609^{76}, manufactured in 1949 in Poland by Fablok, was restored and is now used as an operating museum locomotive and regularly serves tourist and attraction trips on the line (see Fig. 11).

Fig. 11. Steam locomotive 609^{76} - refurbished. *Source*: [21]

In 1942, three four-axle diesel multiple-unit trains and three trailer cars identical to the multiple-unit trains were delivered by the Hungarian company Ganz to serve passenger traffic on the Septemvri - Yakoruda line. They were contracted on 9 December 1939 but arrived in August 1941. They were prepared for trial runs at the end of the year. Due to necessary adjustments to the railway in the Septemvri - Velingrad section, they were put into service on 10 August 1942.

They were series 81. They consisted of three coupled coaches, each with six second-class passenger seats in a self-contained compartment and 35 seats, which were wooden and were third-class, in a typical passenger compartment - saloon. An engine and baggage compartment, a toilet, and a heating cabin separate the two passenger compartments. Unfortunately, photographs of the 81-00 series are not available, but the locomotives are identical in appearance to those of the 82-00 series (Fig. 12).

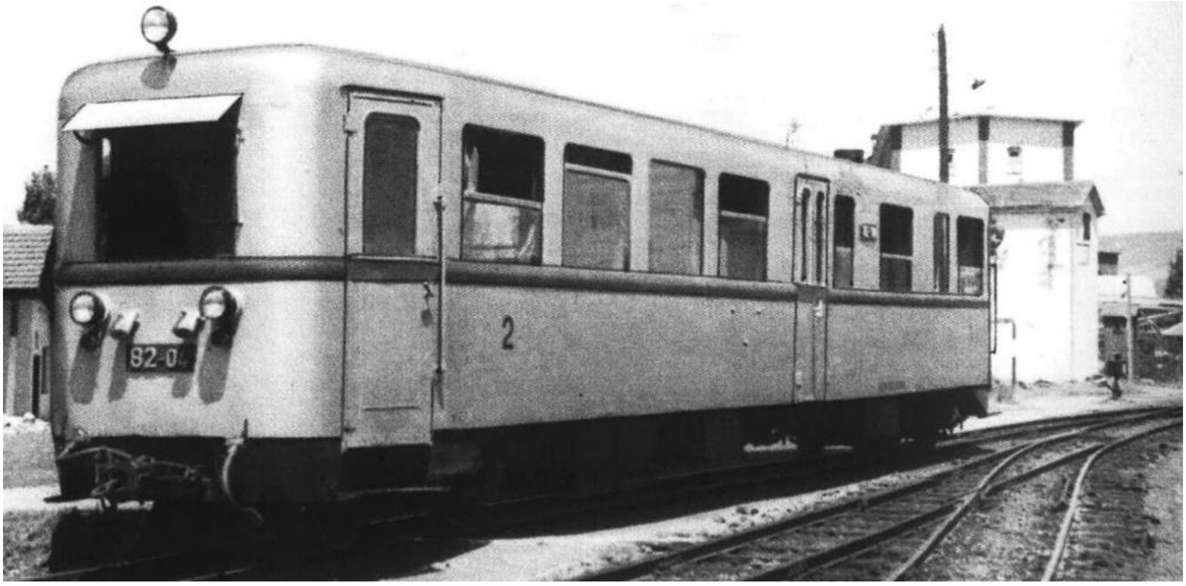

Fig. 12. Diesel locomotive 82-04. *Source:* [22]

Series 81-00 locomotives have been in service for 25 years. None of them are extant today. With the delivery of the first Henschel diesel locomotives, the Kassel series 75 (see Fig. 13), the use of steam locomotives was discontinued [24].

Fig. 13. Diesel locomotive 75 006.7. *Source:* [23]

In 2022, the thirty-four year old diesel locomotive 77.002.4 (see Fig. 14) was overhauled in the Ruse plant of Express Service Ltd. and received a certificate of eligibility for the railway network in Bulgaria.

Fig. 14. Locomotive 77.002.4 – renovated. *Source*: [25]

The repair was highly complex and lasted a year and three months. The refurbished locomotive has been completely replaced with a new environmentally friendly and more economical diesel engine, a newly built digitalized control panel, and an air conditioning system in the control cab. Under the narrow gauge locomotive modernization contract, the plant is also modernizing another locomotive for the line.

Passenger services on the narrow gauge line from Saranbey Station to Lazhene Station began in 1926 with the purchase of the first four narrow gauge cars. All were third class, without compartments, and with typical wooden bench seats of the time (see Fig. 15).

Fig. 15. Retro passenger car – renovated. *Source*: [26]

At each end of the carriage are open platforms resembling terraces. The wagons were manufactured in the Koprivnicka Vozovka AKC SPOL Factory. In 1939, four more wagons were delivered from the factory of the German company Bautzen, and two years later, eight new passenger wagons.

They were similar to the first but had a separate compartment with red upholstered soft seats - second class. After abolishing the third class in the Bulgarian State Railways on June 1, 1956, quite mechanically, the second class became the first and the third - the second.

In 1968, the Bulgarian plant in the town of. Dryanovo produced new second-class passenger cars without compartments for the narrow gauge line (see Fig. 16), which, after two years of testing and improvements - in 1970 - were put into regular service on the line.

By 1974, several more batches of the same carriages were produced and delivered. In addition, a van car and a buffet car were constructed on their model.

Fig. 16. Passenger car – Bulgarian model. *Source*: [27]

Fig. 17. Passenger car – renovated. *Source*: [28]

The modern development of passenger transport on the line is carried out with refurbished Bulgarian carriages with modern and comfortable interiors (see Fig. 17 and Fig. 18), which seriously increases the quality of the transport service.

Fig. 18. Wagon interior – renovated. *Source*: [29]

The first specialized freight cars were delivered in 1926 to develop freight traffic on the narrow-gauge railway. Over the next 76 years, freight transport on the line increased enormously. Hundreds of freight wagons were delivered - vans, flatcars, tank wagons, bulk wagons, etc.

Unfortunately, after 1990, the volume of freight transport drastically decreased, and gradually, the freight traffic on the Septemvri - Dobrinishte line came to a complete halt in 2002. Thus, the only freight wagons available today (see Fig. 19) were abandoned to rust on the tracks at the Septemvri, Velingrad, Razlog, Bansko, and Yakoruda stations.

Fig. 19. Freight wagons - abandoned at Septemvri station. *Source*: [30]

The train service operations in the inner tracks of the larger stations on the line after 1961 are served by different models of shunting diesel locomotives: Deutz series 91-00; "Henschel" - Kassel series 92-00, 92-01 and 80-001.1 (see Fig. 20); series 94-00, 81-002 (see Fig. 21).

Fig. 20. Shunting locomotive - 80-001.1. *Source*: [31]

Fig . 21. Shunting locomotive - 80-002.1. *Source*: [32]

Several technical facilities have been built in the three main sections of the railway line, and engineering solutions have been implemented to overcome the particularities of the specific geography of the mountainous area. These are the basis for the exceptional efficiency of the railway facility, especially in the first few decades of operation when it was the only one in the area's transport infrastructure. Many continue to underpin the opportunities for securing transport accessibility today and make it unique. In total, 35 tunnels (see Fig. 22) with a total length of 2,857.86 m have been dug along the entire railway line. In the section Septemvri - Velingrad, ten tunnels have been built with a total length of 380 m.

Fig 22. The longest tunnel №32 - 314,26 m. *Source*: [33]

Three bridges (see Fig. 23) have been built over the Chepinska River, one each over the Karkaria, Mutnitsa, and Bistritsa rivers. During the construction of the Septemvri-Velingrad section, 97 tonnes of blasting powder, 262,000 capsules, 260 km of Bickford wick, and 1 900 tons of cement were used for all the masonry work. The total amount of construction works and supplies of raw materials and materials amounted to 76 million leva [10].

Fig 23. Crossing and bridge over the Chepinska River. *Source*: [34]

During the construction in 1937, 25 tunnels with a total length of 2477.86 m, nine large bridges, 57 culverts, 24 large retaining walls, and numerous fortifications, earth, rock, and other works were built on the section Velingrad - Yakoruda. After the completion of the extension of the section to Belitsa, the number of bridges and culverts increased to 356 [16].

Contemporary social, demographic, settlement and economic dimensions

The narrow-gauge railway line Septemvri-Dobrinishte continues to perform essential service functions today. Its spatial scope includes seven municipalities of two districts - Pazardzhik and Blagoevgrad, with a total area of 2749.385 sq. km and a total population of 118655 thousand people (see Table 1 and Fig. 24).

Table 1. Main geographical characteristics of the municipalities along the railway line.

Municipality	Area (sq.km)	Population - census 2021. (number)	Average geographical density (people/km^2)	Locations		
				Towns (number)	Villages (number)	Total (number)
Septemvri	349,372	21795	62,39	2	13	15
Rakitovo	246,438	13490	54,74	2	1	3
Velingrad	604,471	32951	54,52	1	20	21
Yakoruda	339,276	9581	28,24	1	7	8
Belitsa	227,477	9206	40,47	1	11	12
Razlog	506,470	18910	37,34	1	7	8
Bansko	475,881	12722	26,74	2	6	8
Total	**2749,385**	**118655**	**43,16**	**10**	**65**	**75**

Based on [35] and own calculations

The area within the railway line's average population density (43.16 people/sq. Km) is below the national average of 58.68 people/sq. Km. The lower average density results from the area being almost entirely mountainous (Fig. 24).

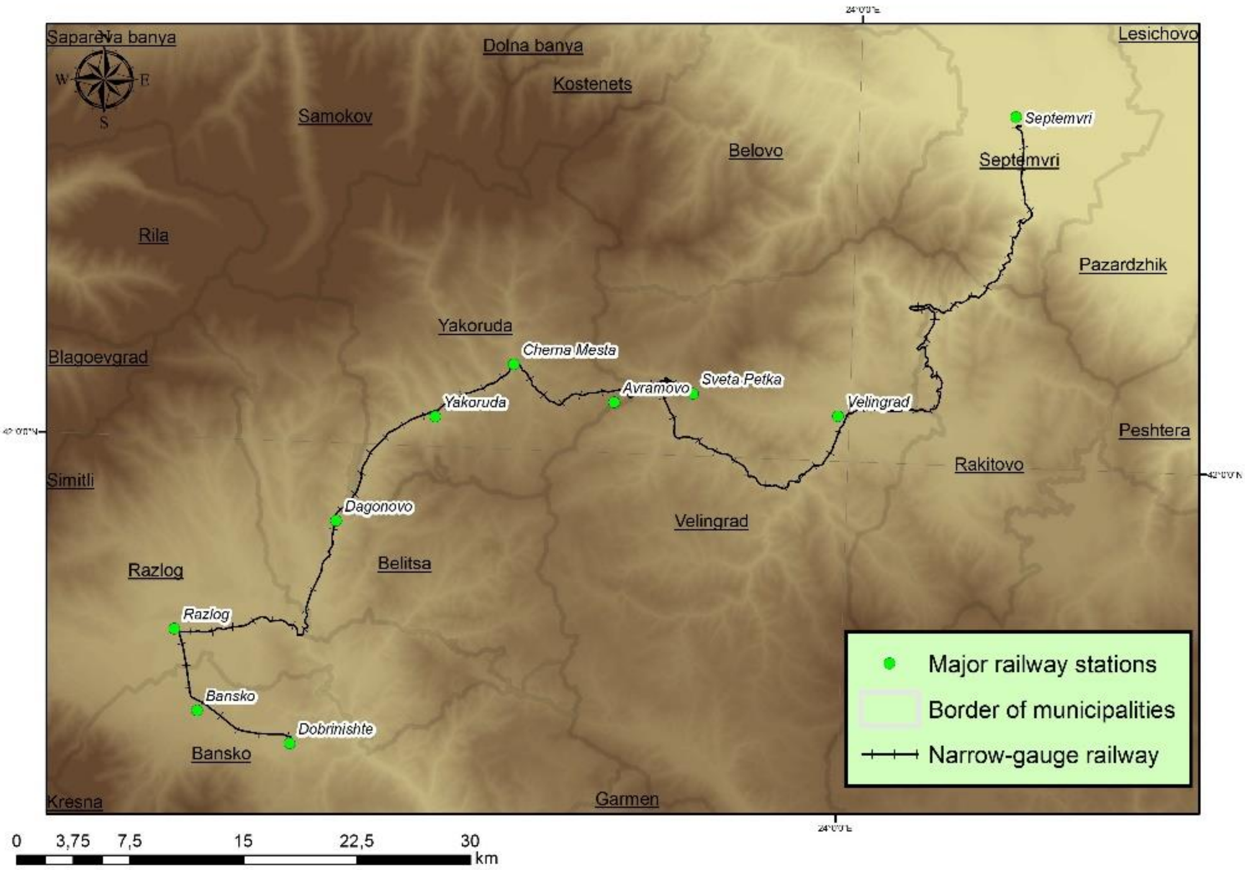

Fig 24. Physical map of the area near the railway (prepared by the authors)

Direct zone of influence

The role of the narrow gauge railway line Septemvri - Dobrinishte for the regional development of the study area can be defined by defining the zones of influence along the route. The part of the territory in contact with the route of the railway, whose development and processes - economic and social, largely depend on the route itself we define as the zone of influence.

According to the methodology of the National Centre for Regional Development (former National Centre for Spatial Development and Housing Policy), the area of influence of a transport corridor is divided into direct and indirect. The former covers the settlements between 3 and 5 km from the route. Regarding the railway, we can look for economic activity around the line and the stations (Fig. 25).

Fig 25. Direct zone of influence near the railway - 5 km buffer (prepared by the authors)

The direct zone of influence (up to 5 km) includes 61 settlements from 9 municipalities.

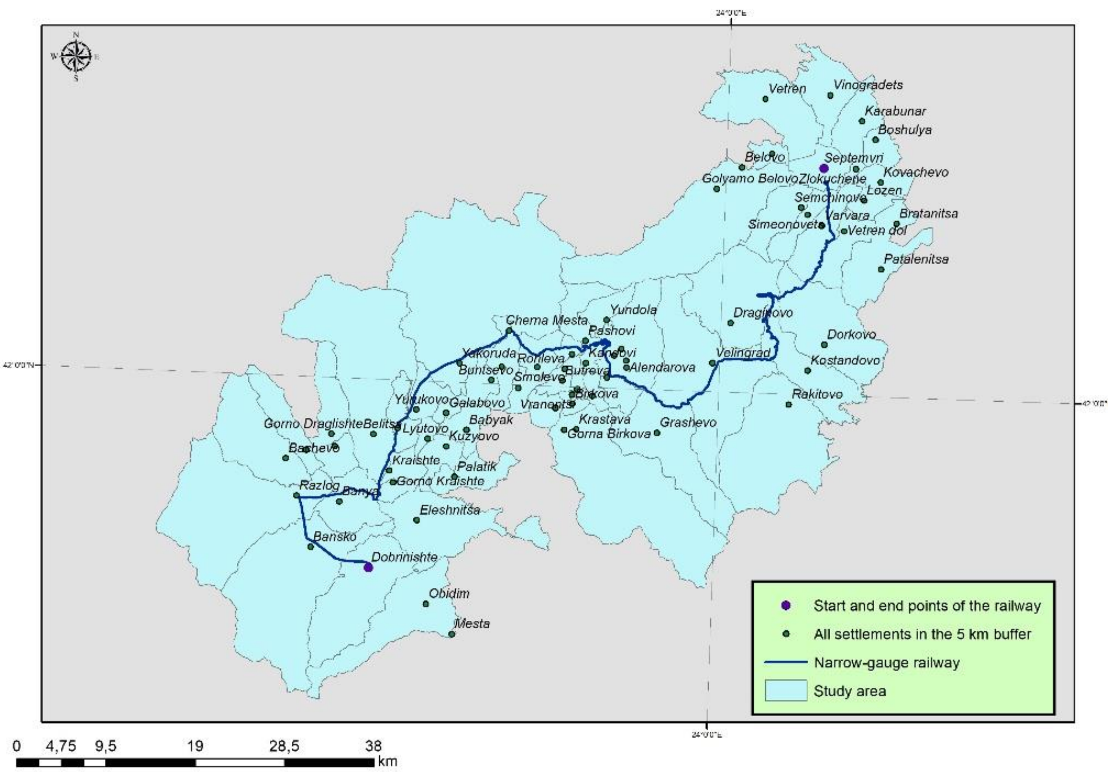

Fig 26. Direct zone of influence near the railway - 5 km buffer with all settlements (prepared by the authors)

This includes 11 towns and 50 villages; 27 are in Blagoevgrad district and 34 in Pazardzhik district (Table 2).

Table 2. Total population of the settlements along the 5 km distance from the railway line.

Municipality	Settlements				Total
	Towns	Villages	In Blagoevgrad district	In Pazardzhik district	
Bansko	2	1	3		3
Belitsa	1	8	9		9
Belovo	1	1		2	2
Pazardzhik		2		2	2
Rakitovo	2	1		3	3
Razlog	1	6	7		7
Septemvri	2	10		12	12
Velingrad	1	14		15	15
Yakoruda	1	7	8		8
Total	**11**	**50**	**27**	**34**	**61**

As of 2023, according to the data of the "GRAO", 141 980 inhabitants live in the 5 km zone from the railway (Table 3, Fig. 27).

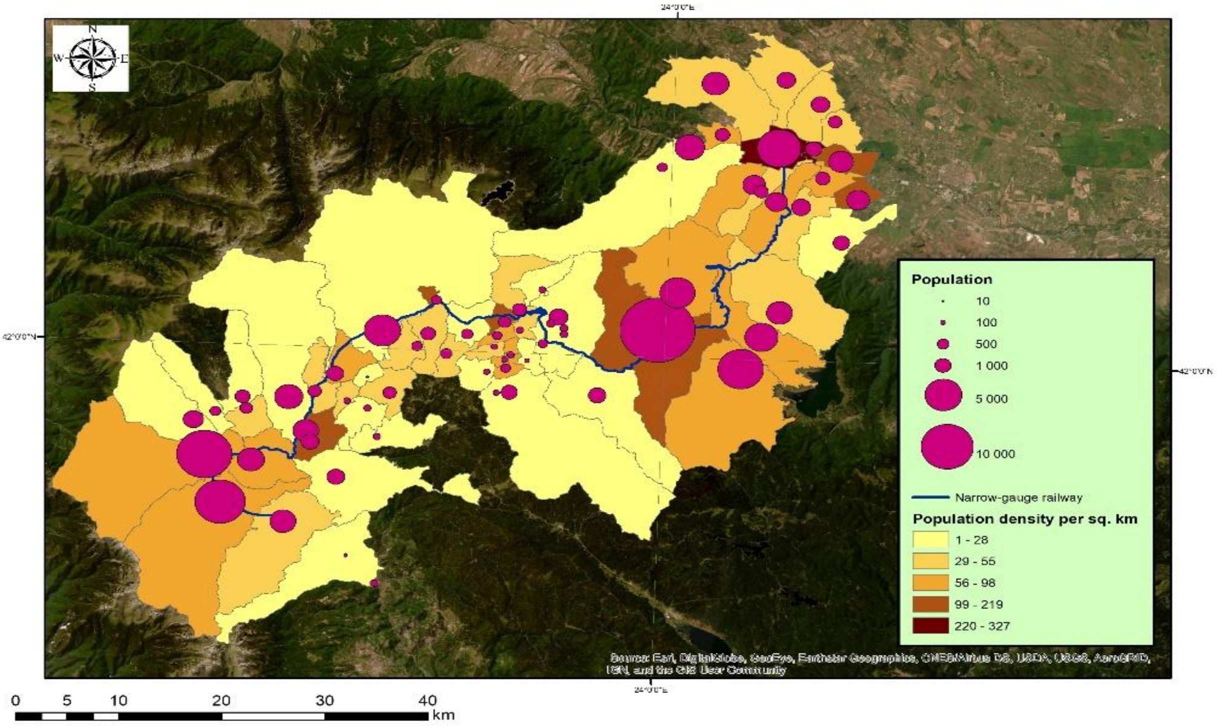

Fig 27. Direct zone of influence near the railway - 5 km buffer with all settlements and their population and population density (prepared by the authors)

Table 3. Total population of the municipalities along the 5 km distance from the railway line.

District/ Municipality	**Towns**	**Total Population**	**Villages**	**Total Population**	**Total number of settlements**	**Total Population**
Blagoevgrad District	**5**	**33679**	**22**	**18570**	**27**	**52249**
Bansko	2	11998	1	74	3	12072
Belitsa	1	3254	8	6118	9	9372
Razlog	1	12843	6	7596	7	20439
Yakoruda	1	5584	7	4782	8	10366
Pazardzhik District	**6**	**53890**	**28**	**35841**	**34**	**89731**
Belovo	1	3895	1	958	2	4853
Pazardzhik			2	3268	2	3268
Rakitovo	2	13301	1	2829	3	16130
Septemvri	2	11573	10	14450	12	26023
Velingrad	1	25121	14	14336	15	39457
Total	**11**	**87569**	**50**	**54411**	**61**	**141980**

The most significant social and demographic sections are those in the high mountainous parts of the municipalities of Velingrad, Yakoruda, and Belitsa. In these areas, the role of the narrow gauge railway continues to be decisive for the daily work and educational journeys of a large part of the population, especially during the winter period, when difficulties in using the roads increase due to the deterioration of the weather conditions.

The significant demographic potential of the two Rhodope municipalities - Velingrad and Rakitovo, as well as their high geographical population density, contribute to the more active use of the transport services of the narrow-gauge railway. The low incomes of the population in the mountainous areas, which rely mainly on this transport due to low ticket prices and significant discounts for students and pensioners, also play a determining role in this respect.

The large number of mainly rural settlements (more than half of the total in the high mountain area), with the typical dispersed character of these areas, further actively contributes to the use of the stations and stops along the railway line on a daily and year-round basis by the population living there.

In the last thirty years, the role of the railway for the economic activities developed in the communities along the route has been gradually reduced. The country's total deindustrialization, particularly the entire Western Rhodope region, is the basis for the suspension of freight traffic on the line, which severely limits its economic effects. Today, the social role of the line overwhelms the other functions it is characterized by. Today, the social role of the line is predominant to its other functions.

New opportunities and perspectives in the development of railway services.

In modern conditions, the narrow-gauge railway Septemvri - Dobrinishte is implementing new alternative forms of use more often. Tourist attraction trips with the restored vintage steam locomotive for various holidays (e.g., traditionally for the students' holiday - 8th December) and other events are becoming increasingly important.

The annual national folklore gathering on the narrow gauge railway under the motto: "With choirs and songs by the narrow gauge tracks" (see Fig. 28 and Fig. 29), which takes place at Avramovo, the highest station on the Balkan Peninsula, has now become a five-year tradition and gives it an additional cultural function.

Fig 28. With choirs and songs by the narrow tracks [36]

Fig 29. With choirs and songs by the narrow tracks, in 2023 [37]

A unique opportunity in the active daily use of the line is provided by the rosary of various spas and spa complexes located near or next to some of its stations (see Fig. 30).

Fig 30. Swimming pool with natural mineral water near the railway [38]

They are an essential factor in modern economic development and especially in the future economic specialization of the mountain region in spa, medical, health, and wellness tourism. It dramatically expands the profile of local, territorial communities while increasing the opportunities to diversify the rural economy with new alternative services and activities.

Entirely new and very promising is the idea that came to fruition on 30 September 2023, when the last Bulgarian narrow-gauge railway welcomed three young scientists in the framework of the European Night of Scientists (see Fig. 31).

Fig 31. European science night in 2023 [39]

Traditionally, such attractive ideas are carried out on Saturdays in the train "Rodopi," departing from Septemvri station at 08:57 and arriving in Dobrinishte at 13:17. The passengers of the fast narrow gauge train had an unusual and unique experience - "Science on board - from the cosmos inside us, through the geological sights along the route of the only functioning railway with a 760 mm gauge in Bulgaria, all the way to the distant Space".

Another critical aspect of the railway is the connection with The E8 European Long-Distance Path. It is an integral part of the European Long Distance Paths (E-routes) network and offers a remarkable opportunity for intrepid hikers and outdoor enthusiasts. The E8 path is approximately 4,700 kilometers long, starting from Ireland's picturesque west coast to Turkey's eastern border.

The route showcases an astounding variety of landscapes, encompassing rugged coastal regions, rolling hills, mountain ranges, serene plains, and the cultural vibrancy of both urban and rural environments. It passes through Ireland, the United Kingdom, the Netherlands, Germany, Poland, Slovakia, Hungary, Romania, and Turkey.

Each nation contributes a unique flavor to the expedition, offering distinct cultural influences, historic landmarks, and awe-inspiring natural landscapes. Highlights include the Irish coastline, the majestic English Lake District, the enchanting Bavarian Alps, the rugged Carpathian Mountains, and the historical treasures of Turkey, among numerous other remarkable sights.

In Bulgaria, the path is mainly in the Rhodopes, and it starts from Yastrebets hut in Rila Mountain and finishes in the village of Mezek. (Fig. 32)

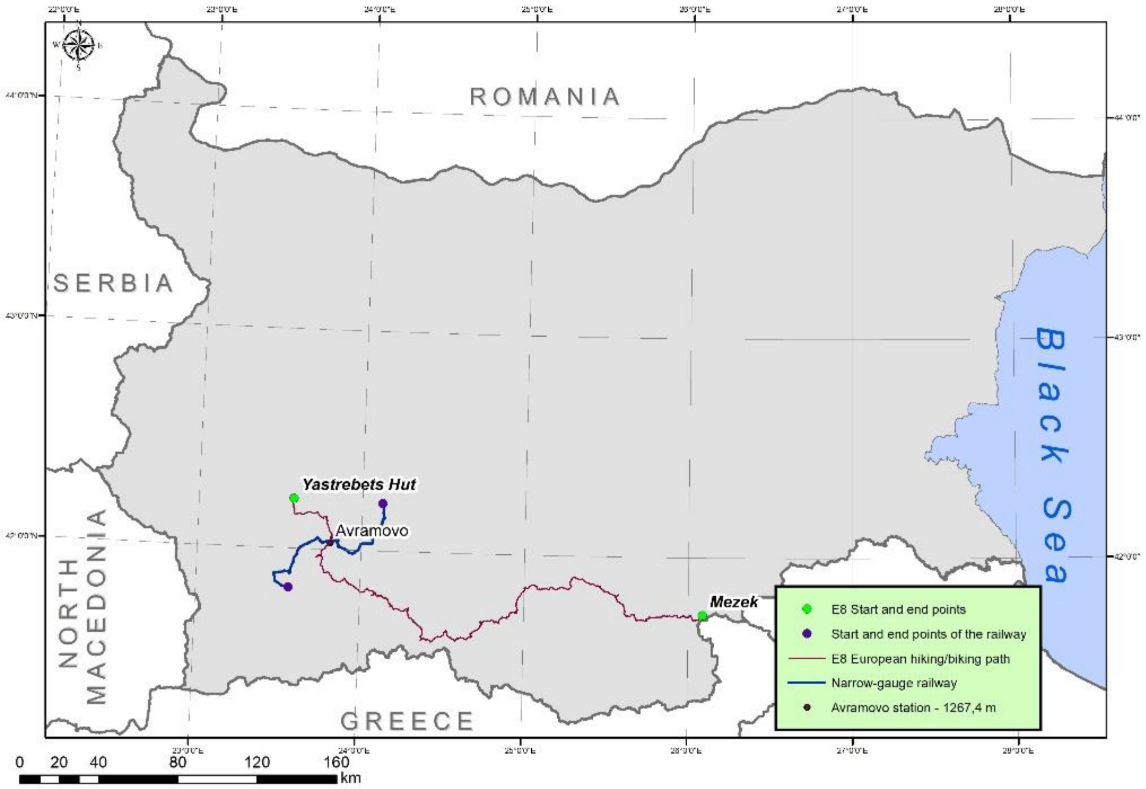

Fig 32. The E8 European Long-Distance Path crosses the railway at the highest railway station in the Balkan Peninsula at Avramovo station (prepared by the authors)

In Bulgaria, the path is about 420 km long, and it passes through some of the most famous places, both in the Rhodope Mountains and the Rila Mountains. One of the first stops along the route is the highest peak in Bulgaria and the Balkans – Musala Peak. With its 2925.4 m, it gives a majestic and challenging start to the trek and the opportunity to see much of the road from above.

The suggested tentative schedule is for 13 days of hiking and 4-5 days by bike. Since August 2023, the Bulgarian railway company – BDZ has had a special carriage that can transport bikes in the train. This is the first carriage ever used for bicycles in Bulgaria and was transformed from a postal carriage (Fig. 33).

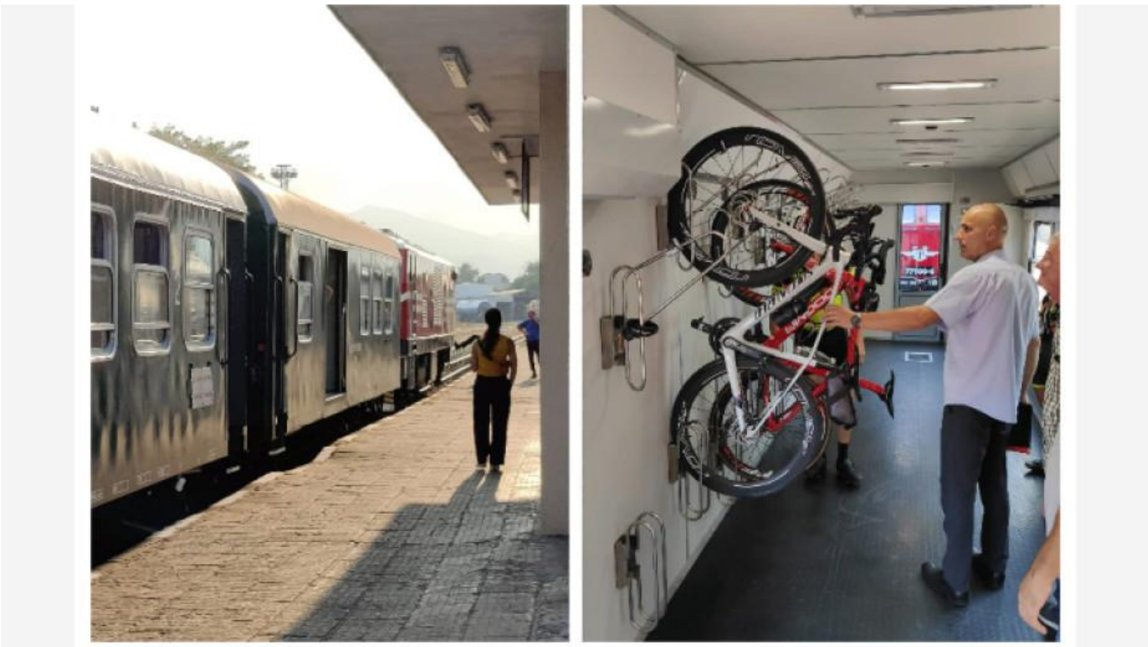

Fig 33. The first carriage for trains in the narrow-gauge railway [40]

As a leading town in SPA tourism, Velingrad is increasingly playing a role in supporting the development of alternative tourism activities in the narrow-gauge railway area. The international route E8 is increasingly promoted in various initiatives of the mineral water bottling company – Velingrad (Fig. 35).

Fig 34. A Girl with a t-shirt promoting the E8 path [41]

CONCLUSION

The development of rail transport in mountainous and rural regions is vital for their modern and especially future sustainable development. The extreme geographical conditions make this mode of transport an alternative in many mountainous areas where other modes cannot provide security and regularity throughout the year and day.

Narrow gauge railways continue to be highly suitable for mountainous terrain with steep gradients and vertical drops that other vehicles cannot negotiate. Their role today and in the future will be structurally decisive for many mountainous and rural areas of the country.

The Rhodope narrow gauge railway remains decisive for the transport services of a significant part of the population and the settlements of the seven municipalities through which its route passes. The predominantly rural character of the territory, with a strong presence of forestry activities in the local economies, allows for a much more active use of the railway's capabilities in serving them.

Increasing the alternative functions of the compositions on the route by diversifying the services offered will ensure safe and sustainable development in the future.

The current state and the prospects for developing the narrow-gauge rail-way Septemvri - Velingrad - Dobrinishte are severe prerequisites for actively upgrading the potential of the railway to meet its 100th anniversary in 2026.

Declaration by Authors

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