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PAST, PRESENT AND FUTURE: THE DIGITAL TRANSFORMATION OF BULGARIAN ROAD NETWORK ¹¹

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***Abstract:** The paper traces the digital transformation of Bulgaria's road network in a historical context. Three main periods are analysed: antiquity and the Middle Ages (until 1878), a period of reconstruction and development (1878-2000) and the contemporary stage of modernization and European integration (after 2000). The emphasis is placed on the third period, examining the introduced digital solutions - electronic tolling, intelligent transport systems and integration with the trans-European networks. The aim is to outline guidelines for the future digital transformation based on the monitored development, taking into account the increasing digitalization, the strategic location of the country and the need for integration with the pan-European road network.*

***Keywords:** Digital transformation, Intelligent transport systems, Traffic management, Road network; Sustainable mobility.*

INTRODUCTION

Bulgaria's road network is going through a complete digital transformation - from traditional methods of management and maintenance to a complex system in which data, automation and intelligent algorithms play a key role. This report analyses this process in three dimensions: the past, to understand where digitalization is starting from, the present, to assess what has been achieved, and the future, to point the way to the full transformation.

Bulgaria has the opportunity not only to catch up, but also to become an active participant in the European digital transport ecosystem, using its strategic location on the Balkan Peninsula.

EXPOSITION

Historical development of the Bulgarian road network

The road network is a vital part of Bulgaria's transport infrastructure, ensuring connectivity between regions and supporting economic development. Its evolution can be traced through three main stages: from antiquity to 1878, roads were mostly cart paths influenced by Roman routes, but the network declined under Ottoman rule due to neglect and forced labor maintenance. After Liberation, Bulgaria prioritized expansion and modernization, increasing the network from about 2,100 km to over 22,000 km by the late twentieth century, while introducing key road arteries, bridges, legislation, and specialized institutions. (Dimitrov, 2013)

From the late twentieth century to today (fig.1), modernization has accelerated through highway construction, rehabilitation of major roads, intelligent transport systems, and integration into European transport corridors, with growing emphasis on sustainability, digitalization, and green technologies.

This historical development highlights the central role of the road network in Bulgaria's connectivity and economic growth.

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Fig. 1. First, second class roads and highways in Bulgaria

Traditional approach to road infrastructure management

For decades, the road network in Bulgaria has been built and managed using traditional methods. The national road network is a system of roads that provide transport links of national importance and routes of state interest, and its management is entrusted to the Road Infrastructure Agency (Road Infrastructure Agency, 2025).

Until the beginning of the 21st century, road management was characterized by a predominantly manual and static approach. The condition of the infrastructure was assessed through visual on-site inspections, and the collection of data on the condition of the road surface, damage and necessary repairs was mainly carried out manually by inspectors. Maintenance planning was static and based on pre-defined schedules, without the ability to dynamically respond to the current state of the infrastructure. Traffic monitoring capabilities were severely limited, which made it difficult to optimize transport flows and respond promptly to problems. Toll collection was carried out through traditional methods such as paper vignettes and physical checkpoints, which was both slower and more difficult to administer and control.

First steps towards digitalization

The process of digital transformation in Bulgaria began gradually in the early 2000s under the influence of European standards and directives. A key moment in this process was the adoption of Directive 2010/40/EU on the framework for the deployment of intelligent transport systems in the field of road transport (Ministry of Transport and Communications, 2013).

The changes in the length of the national road network, in total and by individual classes for the period 2019 – 2024, are presented in the following table (National Statistical Institute, (2019–2024). Only the increase in kilometers of highways is due to new construction, while second-class and third-class roads have increased mainly through changes in their functions in the transport system.

Table 1. Development of the national road network for the period 2019-2024, km

	2019	2020	2021	2022	2023	2024
Highways	790	806	806	825	840	845
First class	2900	2883	2883	2879	2879	2886
Second class	4019	4019	4019	4019	4019	4021
Third-class roads and road connections at intersections and junctions	12170	12209	12217	12219	12230	12234
Total	19879	19917	19925	19942	19968	19986

During the period 2019–2024, the development of the republican road network in Bulgaria shows stability, with minimal changes in the length of the different road categories. The highways increased from 790 km to 845 km, while first-class and second-class roads remained practically unchanged. Growth was observed only in third-class roads, which is insignificant in terms of volume. The total network increased by only 107 km in six years, which indicates a practical stagnation in its expansion.

The lack of significant physical growth outlined in this way emphasizes the importance of digital transformation as a key tool for modernizing the existing infrastructure. The implementation of intelligent transport systems and digital solutions for management and maintenance are essential for increasing the efficiency, safety and sustainability of the road network without the need for major expansions.

Therefore, to overcome the limitations in the current development, digitalization should be a priority as a means of optimizing existing resources and integrating with European transport standards.

Figure 2 presents the distribution of roads in the national road network by 2024 by categories and their relative weight to the total road length.

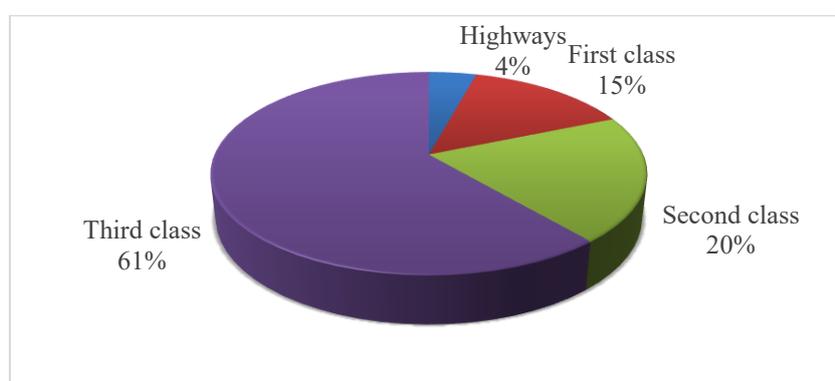


Fig. 2. Relative proportion of roads to the total length of the republican road network, as of 2024

Third-class roads form the largest share – 61% of the total length of the network. This highlights their important role in local connectivity and servicing smaller settlements and industrial areas.

Second-class roads make up 20%, indicating a significant part of the network with connection functions between larger population centers and regions.

First-class roads account for 15%, being the main thoroughfares connecting key cities and providing important transit routes.

Highways are the smallest part – only 4%, which indicates that despite their growth as a network, they are currently still limited in length within the overall road system.

This ratio takes into account that although motorways are key for fast and safe movement, the main part of the burden of road infrastructure is borne by tertiary and secondary roads. This structure imposes the need for systematic measures for modernization and digitalization, especially in smaller and secondary road systems, which are significant for the national economy and social connectivity.

The conclusion points to the importance of balanced development of all categories of roads and the active implementation of intelligent systems and technologies that will optimize the functioning and maintenance of the entire road network in Bulgaria.

The current state of digitalization

One of the most significant changes in the digitalization of the road network is the implementation of electronic toll systems. Since 2019 in Bulgaria, e-vignette and toll are being introduced as a modern way of collecting fees for using the republican road network. This innovation represents a transition from traditional paper vignettes to modern electronic solutions.

The BG Toll system, which administers electronic toll collection, is an important step in the digitalization of the road sector. For heavy goods vehicles, an electronic toll fee has been introduced

instead of a vignette fee, which allows for more precise and efficient collection of funds for the maintenance of the road infrastructure. (BG Toll, 2025)

Ид№	Клас на превозното средство	Клас на емисиите	Брой оси	Начална дата и час на валидност	Крайна дата и час на валидност	Сума	Статус	Действия
2503078064240	Превозно средство <=3.5 тона			01.03.2025 9:50:20	28.02.2026 23:59:59	87,00 лв (44,48 €)	Активна	

Fig. 3 Outlook of BG toll home page in section e-vignette

Bulgaria is actively working on the implementation of intelligent transport systems in accordance with European standards. According to experts in the field, the European Union allocates significant funds every year for financing transport and for the introduction of intelligent transport systems (ITS). Our country is actively participating in the development of the Trans-European Transport Network (TEN-T), which is a strategic initiative of the European Union for the integration of national transport systems. The new regulation defines the elements that comprise the TEN-T network, which requires a high level of digitalization and technological integration.

The Trans-European Transport Network (TEN-T) is a coherent policy of the European Union for the development of multimodal and high-quality transport infrastructure. (Poleganova, 2016). The latest Regulation (EU) 2024/1679, adopted on 13 June 2024, defines the current elements of the TEN-T and sets the requirements for them, replacing the previous Regulation (EU) No 1315/2013. It focuses on multimodality, modern technologies and sustainability, with the TEN-T network serving as a framework for European and national investments in key transport projects and systems.



Fig. 4 Interactive map in the TENtec information system

The European Union actively supports the digitalization of transport. This support includes funding, methodological assistance and the exchange of best practices between Member States.

Despite the progress made, Bulgaria faces a number of challenges in the process of digital transformation. It requires significant financial resources, which is a challenge for the national budget. A balance needs to be struck between investments in new technologies and the maintenance of the existing infrastructure.

First steps towards digitalization

The Ministry of Electronic Governance is actively working on the creation of a comprehensive digitalization strategy will prepare a National Roadmap for the Digital Transformation of Bulgaria by 2030. (Ministry of Transport and Communications, 2020–2030). This initiative will define long-term

goals and priorities in the field of digital transformation of the transport sector. The development of the road network in Bulgaria will be based on the integration of the latest technological solutions as:

- Artificial intelligence and machine learning: These technologies will enable predictive road maintenance, optimization of transport flows and improved safety.
- Internet of Things (IoT): Connected devices will provide continuous monitoring of the condition of the infrastructure and the environment.
- Cloud technologies: Centralized data storage and processing will improve the efficiency of road network management.
- Blockchain technologies: They can provide more secure and transparent management of data and financial transactions.
- Sustainable development

Digital transformation will contribute to achieving the Sustainable Development Goals (SDGs) through (European Commission, 2025):

- Reduction of harmful emissions thanks to optimized traffic
- More efficient use of resources
- Improved energy efficiency of the transport system
- Integration with renewable energy sources

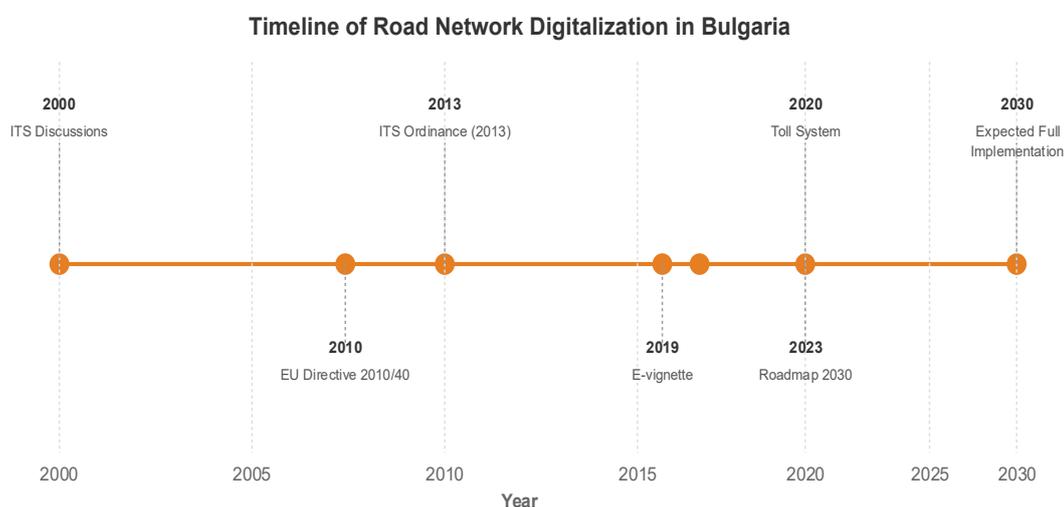


Fig.5 Timeline of road network digitalization in Bulgaria

The successful digital transformation in the transport sector will lead to a number of positive effects for both institutions and society as a whole (fig. 5). It will contribute to improving traffic safety through the implementation of intelligent systems for monitoring and preventing incidents, as well as more effective traffic management through digital modeling and analysis of transport flows. The implementation of digital technologies will allow for the optimization of infrastructure maintenance processes, which will lead to cost reduction and increased efficiency. In addition, digitalization will improve the quality of service to users by providing faster access to information, greater transparency and more convenient travel planning. In the long term, it will also ensure full compliance with European standards and requirements, promoting sustainable development and modernization of the transport system.

CONCLUSION

The digital transformation of the road network in Bulgaria is a complex but necessary process that determines the future of the transport system. From traditional management to intelligent systems, Bulgaria is making significant steps - introducing electronic tolling, ITS and integration into the TEN-T networks. Given the limited physical growth of the network (only 107 km for 2019-2024), digitalization is the key to optimizing existing resources. The structure of the network, where 61% are third-class roads,

requires systematic measures to modernize all categories. The National Roadmap until 2030 will provide the strategic framework for achieving the goals. Only through the consistent implementation of AI, IoT, cloud and blockchain technologies can Bulgaria build a modern, efficient and sustainable transport infrastructure that serves the needs of society in the long term and consolidate the country's role as an important transport hub in Europe.

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