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ANALYSIS OF THE AVERAGE SPEEDS OF PASSENGER TRAINS IN BULGARIA ON THE MAIN RAILWAY ROUTES, ACCORDING TO THE ANNUAL TRAIN SCHEDULE FOR 2025

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Abstract. Rail transport is an important factor in the Bulgarian transport system. The average speed of trains is a critical factor in assessing the efficiency of the system. This article examines the average speeds of passenger trains in Bulgaria, based on the Annual Timetable (AGS) from 2025, paying particular attention to the technical and section speeds on the main railway routes. The report examines the opportunities provided by the planned railway line Yambol-Elhovo-Lesovo-Edirne, with the potential for optimization of transport links in Southeastern Bulgaria and integration with international corridors.

Keywords: average speed; train schedule; analysis; new railway connection; rail transport

1. Introduction

Railway transport is key to the development of the Bulgarian economy and the provision of mobility in Bulgaria. However, outdated infrastructure and limited speeds pose challenges to its efficiency. This analysis is based on data from the 2025 Train Timetable (RRR) to assess and analyse the current state of affairs and identify areas for optimisation. The study focused on the following elements [2, 3]:

- The technical and section speeds of movement on the key railway lines, paying attention to the different categories of trains (Fast, Passenger, Suburban).
- Study of the current speeds at which trains run (BV, PV, KPV) on the main routes.
- Identification of the factors that affect the efficiency of rail transport.
- Assessment of the impact of the introduction of a new railway connection Yambol-Edirne on the common railway network.
- Formulation of recommendations for improving speed indicators.

2. Methods for determining the different speeds in rail transport

This report examines several types of speed indicators in rail transport.

2.1. Definitions of speeds

Several key speed indicators are used in rail transport [8, 9]:

Table 1. Types of speeds in rail transport

Type of speed	Definition	Meaning
Maximum design speed (Vmax)	The highest speed for which the train composition is designed	Determined by the manufacturer
Maximum operating speed	The highest permitted speed on a given section	Depends on infrastructure
Medium Technical Speed (Vtech)	Speed without stopping	Shows the efficiency of the train
Average Section Speed (Vsec)	Speed including braking	Real speed for the passenger
Commercial Speed	Speed from the operator’s point of view	Economic indicator

The following speeds have been taken for the preparation of this report, together with their formulas:

Average Technical Speed (Vtech): The speed of the train without stopping, calculated as the ratio of the distance traveled to the travel time.

(1) $V_{tech} = \frac{\sum L_i}{\sum T_{движ_i}}$, where: L_i – distance, $T_{движ_i}$ – Time in motion;

Average Section Speed (Vsec): Speed including stopping times at intermediate stations, calculated as the ratio of total distance to total time (traffic + stops).

(2) $V_{sec} = \frac{\sum L_i}{\sum (T_{движ_i} + T_{спир_i})}$, where: $T_{спир_i}$– time in stopping.

2.2. Factors affecting speeds

When comparing speeds, various factors affecting speeds are taken into account. The speed indicators of railway transport depend on a complex of interrelated components, which can be divided into three main areas [1, 4, 6, 7]:

Infrastructure elements – this includes: Minimum radius of curves (For standard lines: ≥300m); Longitudinal slope (Limiting the power of the train, as the maximum allowable slope is in the range of 12 – 35‰, depending on the category of the line); Condition of the track (Affecting comfort and safety) and others.

Rolling stock – we can distinguish: Power-to-mass ratio (Affecting acceleration and speed retention, as the ideal values for fast trains are ≥15kW/ton); Aerodynamic performance (reflecting energy efficiency, expressed by resistance coefficient); Braking system (determining safe distances), etc.

Operational factors – including: Train timetable (Capacity utilisation rate: 60 – 85%); Command and control systems (In the presence of systems such as ERTMS, we can reduce the interval between trains ≤3min), etc.

The following tables present the aggregated data for average speeds for the entire network [10, 13, 14, 15]:

Table 2. Report on the average speed of passenger traffic, according to GDV 2025

KPV	PV	BV	Train category	Section
49.6	51.63	68.52	Medium Technical Speed	I railway line Dragoman - Sofia- Plovdiv - Svilengrad
42.99	44.05	64.31	Average Section Speed	
47.78	54.16	74.97	Medium Technical Speed	II railway line Sofia – Gorna Oryahovitsa – Varna
41.48	47.62	71.99	Average Section Speed	
43.43	57.53	74.53	Medium Technical Speed	III railway line Sofia – Karlovo – Varna
38.51	49.25	71.14	Average Section Speed	
48.38	51.49	58.73	Medium Technical Speed	IV railway line Ruse – Stara Zagora
43.37	44.9	53.93	Average Section Speed	
41.33	39.91	45.42	Medium Technical Speed	**IV railway line Dimitrovgrad – Podkova**
37.49	36.38	42.72	Average Section Speed	

KPV	**PV**	**BV**	**Train category**	Section
43.32	50.34	59.3	Medium Technical Speed	**V railway line Sofia – Kulata**
36.3	41.56	53.05	Average Section Speed	
34.84	-	37.33	Medium Technical Speed	**VI railway line Radomir – Gyueshevo**
32.29	-	36.12	Average Section Speed	
55.62	56.73	60.06	Medium Technical Speed	**VII railway line Mezdra – Vidin passenger**
47.75	47.9	54.43	Average Section Speed	
46.85	61.51	90.3	Medium Technical Speed	**VII railway line Plovdiv – Burgas**
41.09	52.54	86.13	Average Section Speed	
60.97	55.43	61.12	Medium Technical Speed	**IX railway line Ruse – Varna**
54.96	49.54	55.47	Average Section Speed	
47.58	53.87	70.96	Medium Technical Speed	**Total for the network**
42.03	46.6	67.07	Average Section Speed	

Based on the presented tables, we can draw the following conclusions:

– The speeds of the High Speed Trains (BV) are the highest, while those of the Suburban Passenger Trains (RRR) are the lowest.

– The biggest difference between the technical and section speed is observed in Passenger Trains (RV), which implies more frequent or longer stops.

– The highest speed was recorded on the VII line (Plovdiv-Burgas) for the BV (86.13 km/h), and the lowest speed was recorded on the VI line (Radomir-Gyueshevo) for the SU (32.29 km/h).

– There are several critical sections: Line IV (Ruse-Stara Zagora), where outdated infrastructure leads to low speeds, and Line VI (Radomir-Gyueshevo), where mountainous terrain limits the speed of movement.

Table 3. Comparison of average speeds for different train categories

Category	Average technical speed (km/h) Vtech (km/h)	Average section speed (km/h) Vsec (km/h)	Difference (%)	Coefficient. efficiency (%)	Difference from the EU (%)
BV	70.96	67.07	5.48	94.5	-35%
PV	53.87	46.60	13.50	86.5	-42%
KPV	47.58	42.03	11.67	88.3	-45%

2.3. Influence of topography

Topography is among the main factors that determine the speed performance of railway infrastructure. In Bulgaria, where the terrain is predominantly mountainous and hilly, the features of the terrain have a significant impact on the planning, functioning and speed parameters of trains. The analysis of individual lines in our country leads to the following observations:

– The Sofia – Karlovo line crosses the Balkan Mountains, which explains the low speed indicators of the SU (36.3 km/h).

– Flat lines (such as Sofia-Plovdiv) allow for higher speeds (over 70 km/h for BV).

– In order to optimise rail transport in difficult mountainous areas, it is possible to use tilting wagon technologies (e.g. Pendolino).

2.4. Comparison with international standards [11]

In order to establish the competitiveness of the Bulgarian railways, it is key to make a comparison with the speed of movement in the other countries of the European Union:

– High-speed rail (Europe): Average track speeds in the range of 200 – 300 km/h (e.g. TGV in France and ICE in Germany) are reported.

– Regional lines (parallel to BV): The characteristic average speed ranges from 100 – 160 km/h (say, in Poland and the Czech Republic).

From the analyses made, we can conclude that the Bulgarian high-speed trains can be compared with the regional trains in Eastern Europe, but they show a significant lag compared to the high-speed rail networks in Western Europe.

2.5. Economic aspects

Train speed is a key factor in the economic efficiency of rail transport. This analysis looks at the relationship between speed of movement and key economic indicators, such as operating costs, revenue, and return on investment. Through the economic analysis of average speeds, we can conclude that increasing speeds leads to an increase in infrastructure maintenance costs (15 – 20% increase in 25% increase in speed), an increase in energy costs and a decrease in the service life of rolling stock. [18]

The increase in investment in rail transport makes it possible to assess the impact of speed on revenues in the following way:

– An increase in speed by 1 km/h leads to a 1.5 – 2% increase in ticket revenue.

– Competitiveness vis-à-vis road transport will improve.

– It creates an opportunity to attract new passengers by significantly reducing travel time.

The following table presents the investment costs needed to increase the speed, as well as the time frame for return on investment [16, 17]:

Table 4. Investment costs for improving train operation

Type of improvement	Expected speed increase	Investment costs	Payback period
Infrastructure modernization	+15 – 25 km/h	1.2 – 1.8 million BGN/km	8 – 12 years old
Introduction of ETCS	+5 – 10 km/h	0.3 – 0.5 mln. BGN/km	4 – 7 years
Renewal of rolling stock	+10 – 15 km/h	2.5 – 3.5 mln. BGN/train	5 – 8 years

3. Opportunities for the construction of a new railway line Yambol – Elhovo – Lesovo – Edirne

3.1. Problems and advantages of building a new line

The lack of direct connectivity between Southeastern Bulgaria (Yambol) and Edirne (Turkey) increases travel time to important European and Asian corridors. The infrastructure in the region of Yambol is partially built, but it is physically obsolete and does not meet European standards and requirements, which makes it unusable. The region is heavily dependent on road transport for international freight and passengers, with the lack of rail transport leading to logistics congestion in the area.

The development of an alternative to the congested Plovdiv – Svilengrad line is a key advantage when considering the new railway line. The creation of a transport hub between Yambol and Edirne (connecting the two industrial zones) will stimulate economic development [19, 20, 23].

3.2. Speed forecasts

The planned speeds for the implementation of the new railway route will generate an increase in the average speed in our country. To achieve maximum precision of the analysis, all the above elements are taken into account, namely:

Terrain: The plain between Yambol and Lesovo is a favorable factor for achieving high speeds and optimizing the construction costs of this section.

Technology: The implementation of innovative security systems (ERTMS) and electrification will play a major role in reducing travel time and increasing safety. The inclusion of automated signaling will limit the dependence on the human factor in the management of trains [5, 21].

Speed requirements: The design speed for the section is 160 km/h, which meets the standards of the European Union.

Logistics of stops: In order to maximize the efficiency of the line, it is planned to limit the section stations to 3 – 4 (Yambol, Elhovo, Lesovo, Edirne).

Based on these and other factors, based on the analysis of the 2025 GDV, the new line could achieve the following results [16]:

Table 5. Forecast speeds on the network Yambol – Elhovo – Lesovo – Edirne

Train category	Forecast Vtech (km/h)	Estimated Vsec (km/h)
BV	90 – 100	85 – 90 (if stops are ≤ 5 min/station)
PV	70 – 80	60 – 65
KPV	50 – 60	45 – 50

3.3. Benefits and potential risks

When compared with the currently operating routes, the newly designed line will exceed the average speed indicators of all currently available railway sections. It will also allow for the optimization of transport routes, which will result in a time saving of ≥1 hour for trains traveling between Sofia and Edirne, compared to the current route through Svilengrad. Another significant positive effect of the new line will be the direct freight trains from Burgas (port) to Turkey and the Middle East, which will reduce the time for the transportation of goods by 20-30% [22].

With regard to the risks associated with this section, it should be noted the uncertainty regarding the financing from European funds and the national budget, as well as environmental aspects, as the line passes close to protected areas (e.g. Sakar), requiring additional assessments [12, 24].

Conclusions

The railway infrastructure has the potential for improvements, especially with regard to the CHP and the old lines. The analysis of average speeds on Bulgarian railways reveals an average level of efficiency with visible leaders and lagging sections. Increasing speeds is critical to attracting more passengers and promoting sustainable transport. In the reconstructed sections, an increase in speeds has been reported, while on the critical, non-modernized lines there is a significant lag and an urgent need for priority investments. The difference between the technical and section speeds (a difference of ~3–7 km/h) indicates a moderate amount of stops and stops, but on slower lines this has a noticeable impact on the overall travel time.

Here are the main recommendations for improving average speeds in the country:

1. Investments in infrastructure renovation;
2. Optimization of schedules in order to reduce the time of stay;
3. Study of the possibilities for increasing the technical speeds in the mountainous areas;
4. A new line Yambol – Edirne will increase the speeds (competitive with European standards), the connectivity of Southeastern Bulgaria with international networks and will stimulate the regional economy through transport integration.

High speeds are a key factor for sustainable transport. Bulgaria has the potential to become a regional leader in the implementation of targeted reforms.

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