

**UKRAINIAN STATE UNIVERSITY
OF RAILWAY TRANSPORT**

FACULTY OF TRANSPORTATION PROCESS MANAGEMENT

Department of Operational Work Management

**METHODOLOGICAL GUIDELINES
for Practical Classes and Independent Work**

in the educational component

“MANAGEMENT OF THE RAILWAY TRANSPORT SYSTEM”

**for students of the second (master’s) level of higher education specialty
D3 “Management. Sustainable Logistics and Supply Chain Management”
full-time education**

Kharkiv – 2026

The methodological guidelines were reviewed and recommended for publication at the meeting of the Department of Operational Management on April 6, 2026, Minutes No. 9.

Methodological Guidelines for Practical Classes and Independent Study in the Educational Component "Management of the Railway Transport System" are recommended for applicants for the second (Master's) level of higher education enrolled in the educational programme "Sustainable Logistics and Supply Chain Management" within specialty D3 "Management. Sustainable Logistics and Supply Chain Management".

Методичні вказівки до практичних занять та самостійної роботи з освітнього компонента «Management of the Railway Transport System» рекомендовано для здобувачів другого (магістерського) рівня вищої освіти освітньої програми «Sustainable Logistics and Supply Chain Management» спеціальності D3 «Менеджмент. Стала логістика та управління ланцюгами постачання».

Author

Assoc. prof. L. I. Rybalchenko

Reviewer

Assoc. prof. O. O. Shapatina

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INTRODUCTION

The primary objective of studying the educational component “Management of the Railway Transport System” is to develop in students a systematic understanding of the principles of railway transport system management, the organization of the transportation process, and the effective coordination of all railway operational units. The course covers issues related to train movement planning, regulation, and optimization, ensuring transportation safety, and improving the efficiency of technical resource utilization.

During the course, students become familiar with the structure of railway management systems, the interaction between their key components, modern approaches to train operations management, as well as the role of dispatching control in ensuring continuous and well-coordinated operation of the railway network. Particular attention is paid to the analysis of operational performance indicators and decision-making processes under real railway operating conditions.

One of the key elements of transportation process management is the train timetable, which defines the sequence, timing, and conditions of train operations. It is based on the rational utilization of line capacity, infrastructure capabilities, and safety requirements. The timetable ensures coordinated operation of stations, locomotive and rolling stock facilities, as well as other services involved in the transportation process.

Mastering the principles of train timetable design, calculation of its key performance indicators, and evaluation of line capacity is an essential component in the training of specialists in railway transport management.

1 PRINCIPLES AND FUNCTIONAL ROLE OF TRAIN TIMETABLING

The train timetable (TT) constitutes the fundamental organizational and technological framework governing the operation of all railway system components. It serves as the central planning document that integrates and coordinates the entire range of operational activities within railway transport. The strict adherence to the timetable is ensured through the proper organization of work processes and the precise execution of technological operations at stations, depots, traction substations, maintenance facilities, and other infrastructure units involved in train operations [3].

From a systems management perspective, the timetable functions as a key instrument for synchronizing the interaction between infrastructure and rolling stock, enabling the stable and efficient functioning of the railway network, while reflecting both operational constraints and technical capabilities of the system and forming the basis for dispatching control and real-time traffic management.

The train timetable must fulfill a number of critical operational and strategic objectives. It should ensure that the demand for passenger and freight transportation is met in a reliable and timely manner, guarantee a high level of traffic safety through appropriate headways and regulatory requirements, and enable efficient utilization of line and station capacity.

In addition, the timetable should support the rational use of rolling stock and traction resources, minimizing idle time and improving asset productivity. It must also ensure compliance with regulations regarding the working and rest time of locomotive crews, as well as provide sufficient time windows for infrastructure maintenance and repair activities across track, signalling, communication, and power supply systems, while adhering to occupational safety standards.

Thus, the train timetable is not only a scheduling tool but also a comprehensive management instrument that determines the overall performance, reliability, and efficiency of railway transport operations.

1.1 Classification and Types of Train Timetables

Within railway systems, including those applied on Ukrainian railways, train timetables are categorized according to their functional purpose, operational conditions, and structural characteristics.

The normative train timetable (NTT) represents the primary regulatory and technological document governing train operations. It is developed on an annual basis by specialized timetable planning and analysis units within the railway transportation services. The NTT establishes standardized operating conditions for all railway divisions involved in train movement management. Typically, a new timetable is introduced at the end of May, prior to the commencement of the summer passenger transportation period. For railway sections with seasonal variations in passenger demand, adjusted versions of the timetable are implemented for winter operations. Official train schedule books are compiled based on the approved normative timetable.

The executed train timetable (ETT) reflects the actual performance of train operations. It is maintained either manually by the train dispatcher or automatically using dedicated software systems. This type of timetable provides a real-time or recorded representation of the execution of the planned (normative or variant) timetable. The analysis of executed timetables forms the basis for evaluating both qualitative and quantitative operational performance indicators of a railway section.

The variant train timetable (VTT) is developed for specific operating conditions, particularly when maintenance or construction “windows” are scheduled. These time intervals, allocated for infrastructure works, impose

constraints on train movements and affect traffic volumes. Variant timetables may be applied either for extended periods or for specific dates, depending on the duration and nature of the infrastructure interventions [1].

From an operational standpoint, train timetables are further classified according to several criteria.

With respect to train speeds, timetables are divided into homogeneous (parallel) and heterogeneous (non-parallel). In homogeneous timetables, trains operating in the same direction maintain identical or similar speeds, resulting in parallel train paths on the timetable diagram. In contrast, heterogeneous timetables involve trains of different categories with varying speeds, leading to non-parallel train paths.

According to the regularity of departures, timetables may be classified as cyclic (periodic) or non-cyclic. Cyclic timetables are characterized by equal time intervals between successive train departures, ensuring regular interval-based operations. Non-cyclic timetables, on the other hand, involve irregular departure intervals and are typically used under variable or constrained operating conditions.

Based on the number of main tracks on a line section, timetables are distinguished as single-track, double-track, or multi-track. On single-track lines, train crossings occur only at passing loops or stations equipped with sufficient track infrastructure. On double-track lines, train paths may intersect both on line sections and within stations, depending on operational arrangements. In multi-track systems, individual tracks may be assigned flexibly to trains in both directions, depending on the adopted traffic management strategy [1,2].

Timetables are also classified according to the number of trains in each direction as paired or unpaired, reflecting balanced or unbalanced traffic flows.

In terms of train sequencing in the same direction, the following categories are distinguished:

non-bunched (spaced) operation, where trains are separated by interstation headways;

bunched (packet) operation, where trains follow each other within block sections or shorter headways;

and partially bunched operation, where only a portion of trains is grouped in such sequences.

Depending on the occupation time of line sections, timetables may be categorized as identical or non-identical. In identical timetables, the time required for a train (on double-track lines) or a pair of trains (on single-track lines) to occupy a section is constant. In non-identical timetables, this time varies depending on operational conditions.

From the perspective of capacity utilization, timetables are classified as saturated or non-saturated. A timetable that ensures full utilization of the capacity of the most restrictive (bottleneck) section is defined as a maximum timetable. In the case of single-track lines, a saturated timetable is one in which train crossings occur at all available passing points, ensuring maximum throughput of the section.

2 INPUT DATA AND METHODOLOGICAL FRAMEWORK FOR TIMETABLE DESIGN

Figure 1 illustrates the layout of a single-track section, which is identical for all variants.

The lengths of block sections, train running times, and station headways are provided separately on a scale diagram or in a task table. The acceleration time is 2 minutes, and the deceleration time is 1 minute.

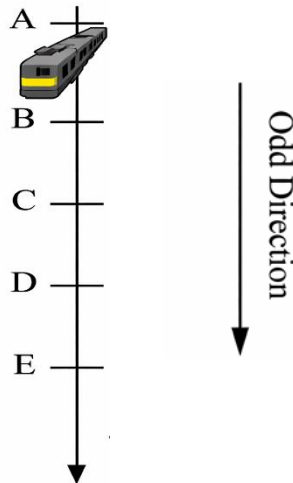


Figure 1 – Schematic diagram of a single-track railway section

Task:

Construct a train timetable for the period from 00:00 to 12:00 (a notional operating day) for the single-track section A–E.

Calculate the technical and sectional speeds of freight trains, the sectional speed coefficient, and the available daily line capacity [4].

Train timetables are constructed on a dedicated scaled grid. Distances between block posts (intermediate stations) are plotted along the vertical axis, while time is represented along the horizontal axis. Horizontal lines indicate the block posts (their axes), whereas vertical lines represent time intervals: thick lines denote full-hour intervals, dashed lines indicate 30-minute intervals, and thin lines correspond to 10-minute intervals. The time scale is typically set from 00:00 to 24:00 hours, or alternatively from 00:00 to 12:00 hours for a notional operating period.

Train movements on the timetable diagram are conventionally represented by straight sloped lines. In reality, however, a train traverses a line section with non-uniform speed, which varies depending on the track profile. These variations are particularly pronounced during train acceleration from a standstill and when

approaching stopping points; therefore, the actual motion of a train along a section is more accurately described by a curved trajectory.

For practical timetable construction, it is more convenient to represent train movements by straight sloped lines, referred to as train running lines (graph “traces”). The horizontal projection of such a running line corresponds to the actual running time of the train over the section.

The passage time (arrival or departure) of a train at each block post is determined by the intersection of the train running line with the axis of the corresponding block post. This time is marked numerically within the acute angle formed by the running line and the block post axis. On sections adjacent to stations that delimit the dispatching district (in this assignment, the terminal stations of section A and E), the train number is indicated above the running line (see Figure 2). For the purposes of this work, freight trains may be assigned numbers starting from 2001. Numbering begins with the first train dispatched after 00:00 hours.

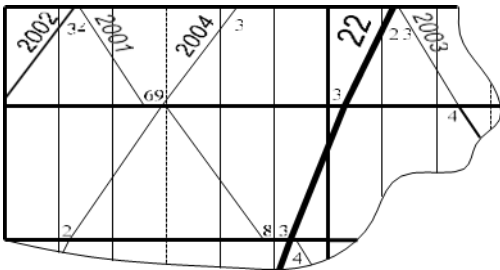


Figure 2 – Train running lines on single-track sections

Trains are numbered according to direction of movement and category of service. Running lines for down (odd-numbered) trains are drawn from top to bottom, while up (even-numbered) trains are drawn from bottom to top. Based on the train timetable diagram, a train schedule is compiled, specifying arrival, departure, and passing times at each block post.

On the left side of the timetable grid, station names, signalling and train control systems used for train operation, and the pure running times of freight and passenger trains are recorded in vertical columns. On the right side, the lengths of line sections are indicated.

When constructing a train timetable, it is essential to take into account that the pure running time of a train over a section must be supplemented by additional allowances. These include the time required for train acceleration after each stop and the time needed for deceleration prior to each planned stop or speed restriction point. These supplementary components are necessary to reflect real operating conditions more accurately and to ensure that the timetable remains both feasible and operationally stable.

Train running lines for different categories of services are conventionally represented using distinct graphical conventions in order to ensure clarity and readability of the timetable diagram. Passenger train paths are typically depicted as continuous red lines, while freight train paths are shown as continuous black lines. Such differentiation allows for quick visual identification of train categories and improves the analytical usability of the timetable.

During timetable development, continuous attention must be paid to the strict observance of all calculated parameters as well as to the mandatory requirements of railway traffic safety. In particular, it is necessary to strictly comply with station headway intervals and, in cases where automatic block signalling is used, train sequencing intervals within a moving block or train pack formation. These constraints ensure safe and conflict-free train operations under conditions of line capacity utilisation.

A station interval is defined as the minimum time interval required to perform all necessary operational procedures at a station associated with train reception, dispatch, and passage, while maintaining safe separation between successive train movements. Station intervals are fundamental regulatory

parameters that govern the safe organisation of train traffic at intermediate and terminal stations.

The principal types of station intervals include the interval of non-simultaneous arrival (τ_H) and the crossing (meet/pass) interval (τ_C). The interval of non-simultaneous arrival (Figure 3 top line) defines the minimum time separation required when trains arrive at a station in a coordinated sequence from different directions. The crossing interval (Figure 1.3 bottom line) defines the minimum time required to safely organise the crossing or passing of trains on single-track sections, ensuring that conflicting train movements do not occur simultaneously [1, 4].

These interval constraints form an integral part of timetable design and directly influence line capacity, train sequencing, and the overall safety and efficiency of railway operations.

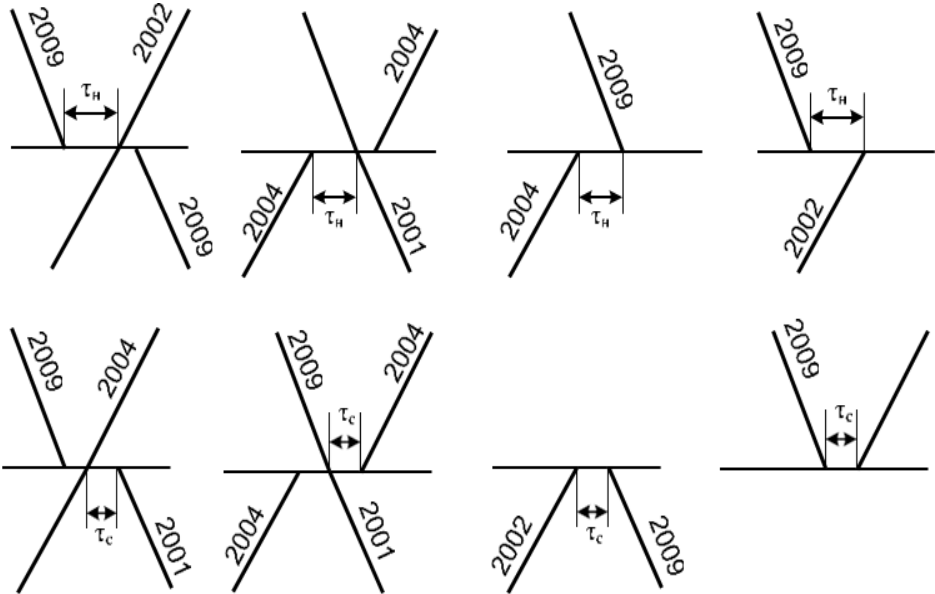


Figure 3 – Interval diagrams: non-simultaneous arrival; train crossing

3 DESIGN OF A PAIRED HOMOGENEOUS (PARALLEL) TRAIN TIMETABLE

If the task requires the construction of a paired, parallel, non-batch train timetable for a single-track section, the development of the parallel timetable should begin with the identification of the critical (limiting) line section within the given route. In particular, priority must be given to the section whose occupation time by a pair of trains (i.e., the timetable cycle or period) is the greatest. This approach is justified by the fact that the line capacity of a railway section is defined as the maximum number of trains that can be processed over a 24-hour period under given technical and operational constraints.

The calculation of available line capacity is performed based on the optimal train-passing scheme over the limiting section, under which the timetable cycle is minimized and, consequently, the line capacity is maximized. In other words, the objective is to identify such a train meeting and crossing arrangement that ensures the shortest possible occupation of the critical section by consecutive train movements, while fully complying with all safety requirements and operational constraints [5].

To achieve this, it is necessary to analyse and compare alternative train movement schemes through the limiting section (see Figure 4). Each variant of train interaction is evaluated in terms of its impact on the occupation time of the section, the resulting timetable period, and the achievable throughput. The optimal scheme is then selected as the one that provides the most efficient utilisation of the limiting section while maintaining safe train operations.

This comparative analysis forms the methodological basis for determining the maximum available capacity of a single-track railway line and is a key step in the design of a rational and efficient train timetable structure.

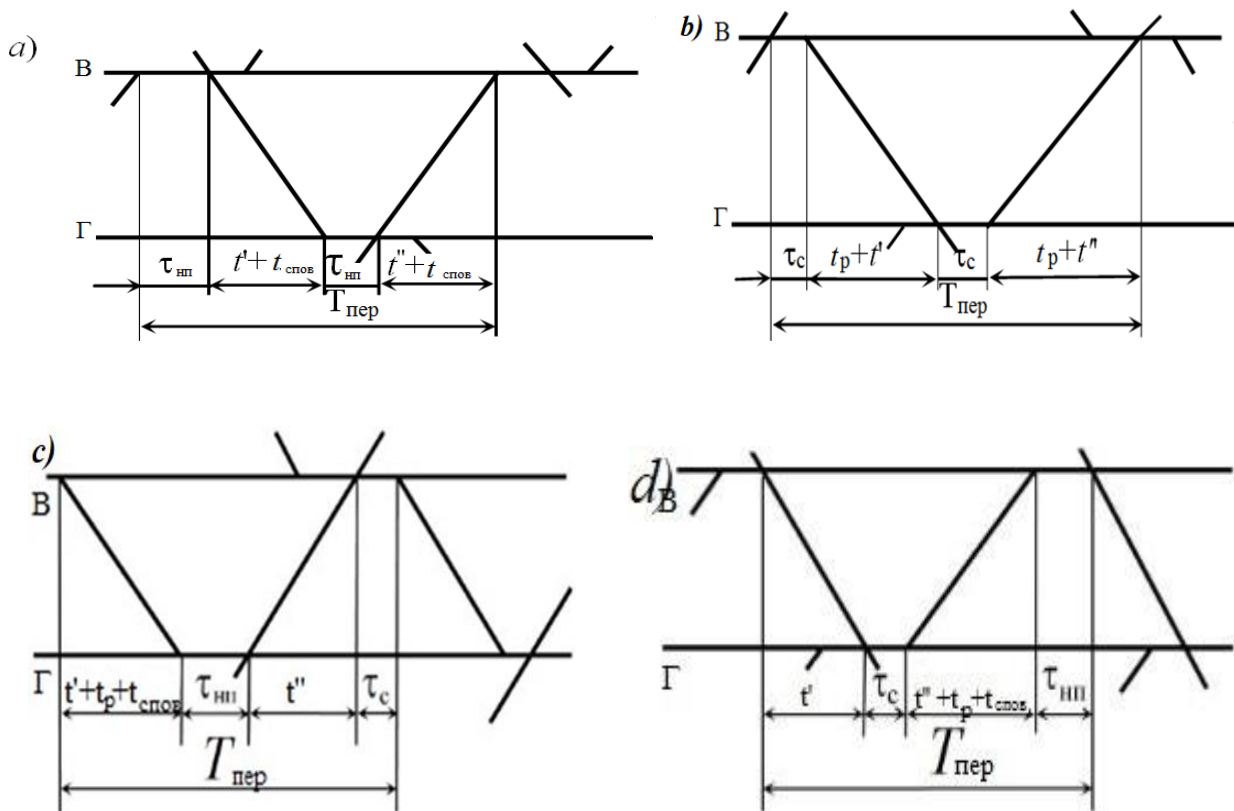


Figure 4

Formulas for calculating the timetable period ($T_{\text{пер}}$) based on the cases presented above are given as follows:

$$a) T_{\text{пер}} = t'_{\text{не}} + 2t_{\text{спов}} + 2\tau_{\text{нп}} + t'_p; \quad (3.1)$$

$$b) T_{\text{пер}} = t'_{\text{не}} + 2t_r + 2\tau_s + t'_p; \quad (3.2)$$

$$c, d) T_{\text{пер}} = t'_{\text{не}} + t'_p + \tau_{\text{нп}} + \tau_s + t_r + t_{\text{спов}}, \quad (3.3)$$

where $t'_{\text{не}}$ – pure running time of the odd-numbered train on the limiting line section, min;

t'_p – pure running time of the even-numbered train on the limiting line section, min;

- τ_{np} – station interval of non-simultaneous arrival of trains, min;
- τ_s – station interval of train crossing (passing), min;
- t_r – additional time for train acceleration, min;
- t_{spov} – additional time for train deceleration, min.

The procedure for plotting train movements on the timetable is as follows. The plotting of trains begins with the limiting section. First, a train in one direction is scheduled, and then, after the expiration of the station crossing interval, a train in the opposite direction is scheduled. This process continues until the end of the day.

Train paths that terminate at the end of the day within the section must be continued at the beginning of the next day. Therefore, it is recommended that the plotting of train trajectories on the limiting section should not start exactly at 00:00, but rather with a shift of 10–20 minutes from the beginning of the grid, in order to facilitate the alignment of the end and the beginning of the timetable [1].

Figure 5 presents an example of a constructed parallel timetable for a section where the limiting segment is C–D. The departure time of even-numbered train No. 2016 onto the limiting section from station C is 00:10. The train passes the adjacent station B without stopping at 00:23 ($00:10 + 1 \text{ min} + 12 \text{ min} = 00:23$).

The routing of the trajectory line for odd train № 2015 on the limiting section begins from station B. To the time of passage of train № 2016 through station B, the crossing interval $\tau_s=1 \text{ min}$ is added, which determines the departure time of train № 2015 (00 h 24 min).

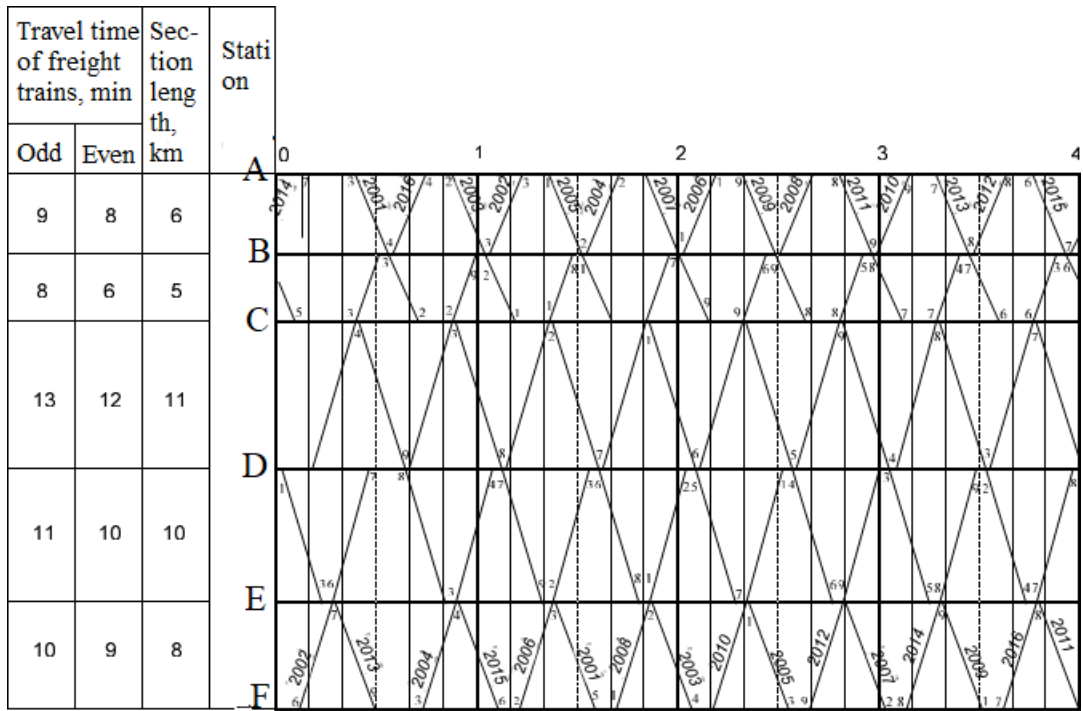


Figure 5 – Single-track even parallel train timetable graph

Train № 2015 will pass station D at 00 h 38 min (00 h 24 min + 1 min + 13 min = 00 h 38 min) and arrive at station E at 00 h 50 min (00 h 38 min + 1 min + 11 min = 00 h 50 min). Even train № 2002 will depart from station D onto the limiting section after the crossing interval $\tau_s=1$ min, i.e., at 00 h 39 min (00 h 38 min + 1 min). Subsequently, the trajectory lines of odd trains are plotted in the same manner until the end of the timetable grid. In total, 8 pairs of freight trains must be scheduled.

After completing the timetable for the limiting section and plotting even trains on section C–B and odd trains on section D–E, the trajectory lines of odd trains are plotted on section A–B and even trains on section E–F. The plotting of trajectory lines of odd trains on section A–B must be performed considering the arrival time of trains at station B.

For example, the arrival time of train № 2001 at station B is determined as follows: from the arrival time of train № 2016 at this station (00 h 30 min), the non-simultaneous arrival interval $\tau_{np} = 3$ min is added, which gives the passage

time of train № 2001 — 00 h 33 min. By subtracting from 00 h 33 min the net running time of the odd train $t'_{ne} = 9$ min and the acceleration time $t_r = 1$ min, the departure time of train №2003 from station A is obtained — 00 h 23 min [4].

The plotting of even trains on the timetable for the line sections begins from the moment they pass station E, based on the arrival time of odd trains at this station and taking into account the non-simultaneous arrival interval between odd and even trains.

Similarly, odd trains are plotted on sections D–E and E–F, while even trains are plotted on section E–F.

When drawing up a train schedule, it should be assumed that, as a rule, trains pass through one intermediate checkpoint without stopping, and through the next one with a stop.

However, it is necessary to ensure compliance with the specified crossing interval throughout the process.

The stopping of freight trains at stations is envisaged only for crossing and overtaking operations, whereby, in the case of two opposing trains, one must pass through the station without stopping. The crossing interval must be strictly observed at all intermediate stations. The clearing of a block section by a train indicates the necessity of dispatching the opposing train that is standing at the station. An exception to this rule is the case in which the interval for non-simultaneous arrivals is not maintained at an adjacent station, resulting in both trains being brought to a stop. In such cases, the crossing interval may be increased, but only to the extent that the interval for non-simultaneous arrivals at the adjacent station corresponds to the prescribed standard value.

On a limiting block section that is not the final one, it is permitted to increase one crossing interval in order to “close” the train timetable. For stations A and F, which delimit the line section, the crossing interval may exceed the specified value, since all trains are required to stop there due to technical necessity.

The train timetable is conventionally assumed to be repetitive (closed) in four-hour cycles. Therefore, the position of each train on the section after 4 hours is transferred on the timetable to 0:00 hours, and within the remaining free 10–20 minutes at the beginning of the schedule, the train paths are coordinated. At this stage, previously plotted train trajectories may be adjusted in order to eliminate unjustified stops.

To avoid errors in constructing the train timetable, it is necessary, at the points where train paths intersect the station axis, to immediately indicate in the obtuse angle the last digit of the time of departure, arrival, or passage of trains. For trains passing through a station without stopping, the digit is recorded only once on the section traversed by the train.

4 DESIGN OF A HETEROGENEOUS (NON-PARALLEL) TRAIN TIMETABLE

The construction of a non-parallel train timetable begins with the plotting of high-speed train paths. High-speed trains, according to the assignment, do not have scheduled stops at stations B, C, D, and E; therefore, an additional 1 minute is added only for acceleration and deceleration on the sections adjacent to stations A and F (Figure 6).

The construction of freight train paths on a non-parallel train timetable should begin with the limiting block section. In this stage, the train graph lines should, wherever possible, be arranged symmetrically, in accordance with the previously selected train dispatching and routing scheme. Unlike a parallel timetable, in a non-parallel system the plotting of freight train paths on the limiting section must take into account the operational impact of passenger train movements, including their priority and prescribed running times [1].

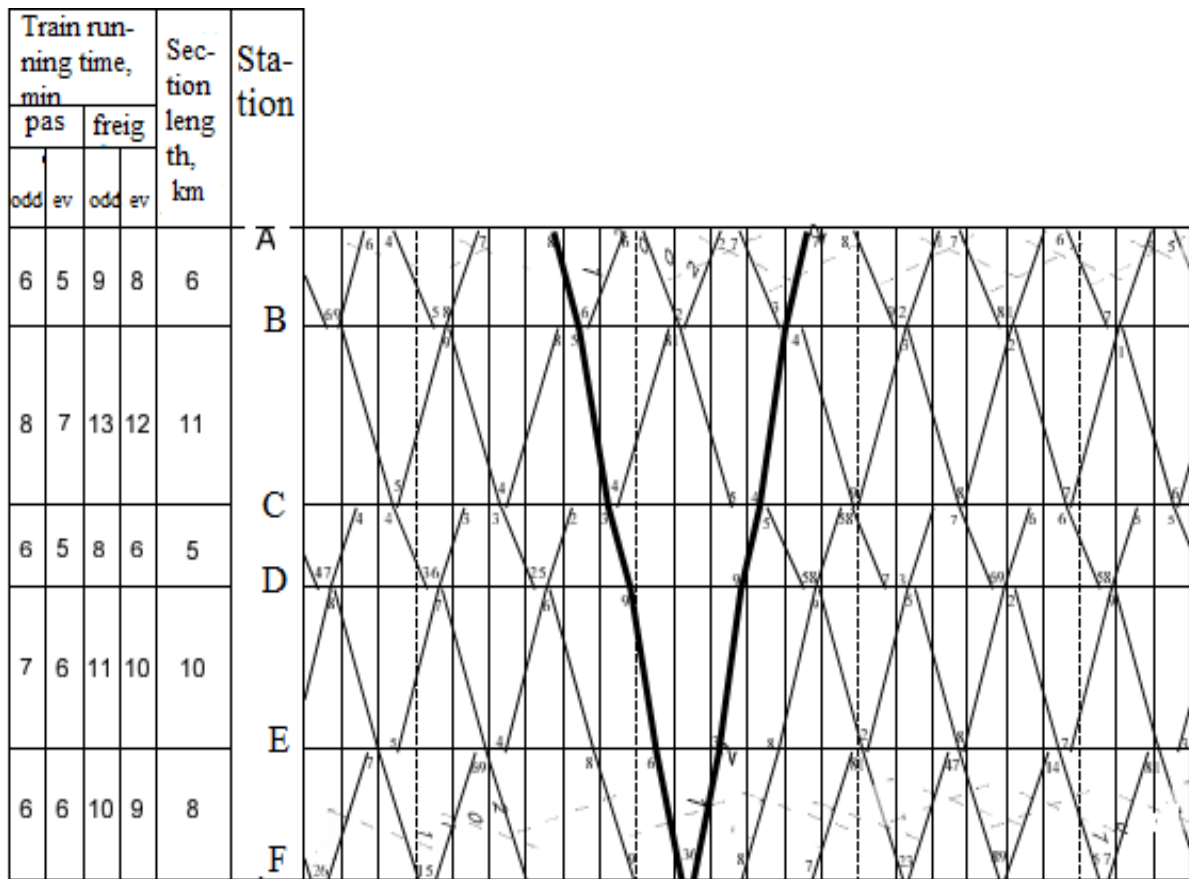


Figure 6 – Non-parallel train timetable

The utilisation of the limiting block section may be initiated in the intervals between scheduled passenger trains, ensuring optimal utilisation of track capacity while maintaining operational safety margins. The timetable should include no fewer than six pairs of freight trains to ensure adequate traffic density and line throughput.

When dispatching two consecutive trains in the same direction (a train pack), the prescribed headway interval between trains must be strictly maintained in accordance with signalling and operational safety requirements.

The construction of a train timetable is a complex combinatorial task; therefore, it is recommended to draft the timetable initially in pencil, iteratively refining and adjusting the train paths in order to achieve the most efficient and operationally optimal solution.

5 ASSESSMENT OF TRAIN TIMETABLE OPERATIONAL PERFORMANCE AND CAPACITY INDICATOR

The train timetable is characterised by both quantitative and qualitative performance indicators. Quantitative indicators include the number of freight and passenger trains scheduled on the timetable, as well as the volumes of loading and unloading operations that can be accommodated under the given timetable conditions, among others.

The main qualitative indicators of a train timetable include technical speed, sectional (line) speed, and commercial (route) speed (calculated separately for freight and passenger trains), the speed coefficient, average daily locomotive mileage, average dwell times of through trains and locomotives at intermediate stations, and the average train weight.

Technical speed is defined as the average speed of train movement over a railway section, taking into account additional time for acceleration and deceleration, and excluding dwell times at intermediate stations:

$$V_{tech} = \frac{\sum NL}{\sum NT_{run}}, \quad (5.1)$$

where N – the maximum line capacity (i.e., the maximum number of trains that can be operated over the railway section per day);

L - the distance between stations A and F;

T_{run} – the running time of trains over the entire section (including acceleration and deceleration phases, but excluding dwell time at intermediate stations).

Available line capacity is the capacity that can be achieved under the existing technical equipment and infrastructure of the railway line. Line capacity

is calculated using analytical methods and, in more complex cases, verified graphically through the construction of maximum train timetables [5, 6].

When applying the analytical method, the daily available capacity of a single-track section under a parallel, even-direction, non-bunched timetable is determined by the following formula:

$$N = \frac{(1440 - t_{tech})\alpha_r}{T_{per}}, \quad (5.2)$$

where t_{tech} – the duration of technological allowances (operational intervals) incorporated into timetable construction (for single-track lines – 60 minutes; for double-track lines – 120 minutes);

α_r – the reliability coefficient of technical equipment operation (for electrified double-track lines – 0.92...0.98; for double-track lines with diesel traction – 0.90...0.96; for single-track lines – 0.89...0.95);

T_{per} – the timetable period, i.e., the time of occupation of the block section by a characteristic group of trains for the given timetable type, whose arrangement repeats cyclically throughout the day.

Sectional speed is defined as the average speed of a train between two locomotive change stations, taking into account dwell times at intermediate stations (calculated separately for freight and passenger trains):

$$V_{sec} = \frac{\sum NL}{\sum NT_{run} + \sum NT_{stop}}, \quad (5.3)$$

where T_{stop} – the time spent on dwell (stopping time) at intermediate stations;

T_{run} – the running time of trains over the entire section (including acceleration and deceleration phases).

The sectional speed coefficient characterises the quality of timetable construction and the efficiency of train path planning:

$$\beta = \frac{V_{sec}}{V_{tech}}. \quad (5.4)$$

The train timetable is developed based on the maximum traffic volumes forecast for the period of its validity. In addition, in cases of significant fluctuations in transport demand, as well as for the execution of scheduled infrastructure works—such as track reconstruction and major maintenance, inspection and repair of the overhead contact system, and electrification projects—alternative timetable variants are prepared and implemented for specific periods [1, 2, 3].

Within timetables designed for large-scale maintenance or construction activities, so-called “track possessions” (windows) are provided, during which specific block sections are temporarily handed over to track maintenance or construction organisations for exclusive use.

The train timetable is compiled simultaneously for the entire railway network for a period of one year and is introduced into operation in May. For the winter period, it is adjusted to account for seasonal variations in traffic volumes. Based on the timetable, train schedules are issued for both operational (service) and public use.

In parallel with, and on the basis of, the train timetable, a locomotive circulation (turnaround) schedule is also developed.

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