UKRAINIAN STATE UNIVERSITY
OF RAILWAY TRANSPORT

FACULTY OF TRANSPORTATION PROCESS MANAGEMENT

Department of Operational Work Management

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MANAGEMENT OF THE RAILWAY TRANSPORT SYSTEM

Lecture Notes

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The lecture notes cover the fundamentals of railway transport organization and management, the structure and technical equipment of railways, the functioning of track, locomotive and carriage facilities, power supply, signaling and communication systems, as well as the principles of transportation process organization and operational train traffic management.

Recommended for second (Master's) level higher education students of the educational programme "Sustainable Logistics and Supply Chain Management" in specialty D3 "Management. Sustainable Logistics and Supply Chain Management".

Конспект лекцій охоплює основи організації та управління залізничним транспортом, структуру та технічне обладнання залізниць, функціонування колійного, локомотивного та вагонного господарства, систем електропостачання, сигналізації та зв'язку, а також принципи організації транспортного процесу та оперативного управління рухом поїздів.

Рекомендовано для студентів другого (магістерського) рівня вищої освіти освітньої програми «Стала логістика та управління ланцюгами поставок» за спеціальністю D3 «Менеджмент. Стала логістика та управління ланцюгами поставок».

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Reviewer

Associate Professor H. S. Baulina

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INTRODUCTION

Transport and logistics are important components of the modern economy and play a key role in ensuring the efficient functioning of supply chains, the development of international trade, and sustainable economic growth. Railway transport, as one of the most environmentally friendly and economically efficient modes of transport, occupies an important place in the system of sustainable logistics solutions and transport flow management.

The modern railway transport system is a complex set of interconnected technical, organizational, and managerial elements, the effective functioning of which ensures the continuity of the transportation process, optimization of transport costs, transportation safety, and reliability of logistics operations. Particular importance is attached to the organization of transportation, infrastructure management, operational planning, and coordination of the activities of railway transport structural units in the context of the development of modern logistics systems.

The lecture notes examine the fundamentals of the functioning and management of the railway transport system, the structure and technical support of railways, the principles of organizing the transportation process, the features of the operation of the main railway facilities, as well as issues of operational train traffic management and ensuring the efficiency of transport and logistics processes.

The content of the lecture notes is based on the curriculum of the educational component “Management of the Railway Transport System” within the educational program “Sustainable Logistics and Supply Chain Management”. The lecture notes are aimed at developing students’ systematic understanding of the principles of railway transport operation, transport process management, and their role in modern logistics and supply chain systems.

The lecture notes may be used by students of the second (Master's) level of higher education enrolled in the educational program "Sustainable Logistics and Supply Chain Management" in the specialty D3 "Management. Sustainable Logistics and Supply Chain Management".

Lecture 1
PURPOSE AND OBJECTIVES OF THE DISCIPLINE. THE ROLE AND IMPORTANCE OF TRANSPORT. BRIEF DESCRIPTION OF MODES OF TRANSPORT AND THEIR INTERACTION. BRIEF HISTORY OF RAIL TRANSPORT. THE FUNDAMENTAL ADVANTAGES OF RAIL TRANSPORT. BASIC PRINCIPLES OF ORGANIZATION OF TRANSPORTATION BY RAIL

The purpose of teaching the discipline "Management of the railway transport system" is to form systematic knowledge of: understanding the conceptual foundations of the construction and functioning of the transport network of Ukraine; structures, devices of railway transport; features of the organization and technology of railway structural units; scheduling trains; principles of calculation of the main operational indicators of railways.

Goals and objectives of the educational discipline.

Modern transport has a developed infrastructure, which includes a variety of infrastructure of all types of transport, the interaction of which performs the continuous process of transporting passengers and cargo in various types of connections.

The study of the discipline "Management of the railway transport system" forms knowledge about the work of transport in general, activity, specific struggle and interaction of different types of transport; advantages, structure, purpose and technologies of work and interrelationship of the main divisions of railway transport and its place and role in the unified transport system; familiarization with important technical means, technical and economic indicators of the operational work of railway transport, the meaning and principles of drawing up a train schedule.

Transport plays a major role in the livelihood of people, connecting the production of products with their consumers, connecting the regions of Ukraine with each other, as well as with other states. Transport also plays a huge role in strengthening the country's defense capabilities [1].

The development of railway transport in Ukraine began in the nineteenth century and played a crucial role in shaping the country's economic and industrial growth. The first railway line within the territory of modern Ukraine was introduced in 1861, connecting the city of Lviv with Przemyśl, which was then part of the Austro-Hungarian Empire. This railway route became an important trade corridor between Eastern and Western Europe [2].

Railway construction expanded quickly in the second half of the nineteenth century. One of the most important projects was the Odesa–Balta railway line, opened in 1866. It significantly improved transportation for agricultural goods and strengthened the economic importance of Black Sea ports.

At the start of the twentieth century, railways had become the foundation of Ukraine's transportation infrastructure. Large industrial regions and major cities such as Kyiv, Kharkiv, and Donetsk were connected through an extensive railway network. Rail transport also provided efficient access to maritime ports located on the Black and Azov Seas.

Among the earliest railway routes were the Przemyśl–Lviv line established in 1861, the Odesa–Balta and Rozdilna–Kuchurhan lines opened in 1865, the Lozova–Marcheve railway launched in 1869, and the Lozova–Oleksandrivsk route with an extension to Nyzhniodniprovsk completed in 1873.

During the late nineteenth and early twentieth centuries, narrow-gauge railways were widely developed in the Carpathian and Transcarpathian regions.

These lines mainly served the timber industry and supported the transportation of wood from mountainous areas. Railway expansion continued throughout the Soviet period with the construction of additional lines, including Luhansk–Lutuhyne in 1921, Chervonoarmiyske–Dobropillia in 1935, and Starobilsk–Kondrashivska–Dolzhansk between 1940 and 1941.

Following World War II, the pace of railway construction decreased, although approximately 5,000 kilometers of new tracks were still added. Many less active railway branches and timber lines were eventually closed. However, the government invested heavily in improving the capacity and technical condition of the main railway routes.

In the 1950s, the Ukrainian SSR became one of the leading Soviet republics in terms of railway density. The electrification of railway lines intensified during the 1960s, which greatly increased transportation efficiency and reduced dependence on steam locomotives.

After Ukraine gained independence in 1991, all railway infrastructure within the country became state property. Later that year, the government established the State Administration of Railway Transport of Ukraine, which united six regional railways into a single national system. This organization later became known as Ukrzaliznytsia, the national railway company of Ukraine.

Today, Ukraine's railway network remains a vital component of the national economy. It ensures passenger transportation, supports freight logistics, and connects the country with European and Asian transportation corridors. Modern railway transport represents a complex system that includes rolling stock, railway tracks, signaling and communication systems, technical equipment, and specialized infrastructure facilities [3].

The main elements of any transport system include several interconnected components.

First, transport systems require vehicles used for moving passengers and cargo. These include automobiles, trailers, semi-trailers, transport tractors, railway wagons, locomotives, aircraft, helicopters, ships, pipelines, containers, pallets, and tank containers.

Second, transport infrastructure depends on communication routes such as railway lines, highways, waterways, air routes, monorail systems, and cable transport lines. These routes form the physical basis for the movement of goods and people.

Another essential component is the system of control and communication. This includes dispatch centers, communication stations, and automated traffic management systems that coordinate and regulate transportation processes.

Transport operations also rely on technical equipment and specialized mechanisms. Examples include loading and unloading machinery, conveyor systems, and equipment designed for packaging and cargo formation.

In addition, transport infrastructure includes numerous buildings and facilities such as railway stations, depots, service and maintenance stations, ports, repair workshops, factories, warehouses, bus terminals, airports, piers, compressor stations, and pumping stations.

All modes of transport together create a unified transport network that combines land, underground, water, and air transportation systems. Land transport includes railways, motor roads, pipelines for oil and gas transportation, modern high-speed systems such as magnetic levitation and air-cushion transport, monorails, power transmission infrastructure, and cable railways. Underground transport is mainly represented by metro systems, while water transport includes both sea and river navigation. Air transport consists of civil and commercial aviation [4].

Transport can also be classified according to its functional purpose. Internal transport operates within factories, industrial enterprises, farms, mines, and quarries, ensuring the movement of materials and products during production processes. Urban transport serves passengers and cargo within city boundaries, whereas suburban transport connects cities with nearby suburban areas, usually within a radius of fifty kilometers. Interregional transport provides connections between neighboring economic regions, while long-distance transport operates over distances exceeding fifty kilometers outside urban areas. International transport is responsible for transportation between different countries and supports global trade and mobility.

Depending on organizational subordination, transport systems are divided into public and non-public transport. Public transport is legally obligated to provide transportation services for both passengers and cargo regardless of the customer. Non-public, or departmental, transport belongs to specific enterprises, institutions, or organizations and is mainly used for their internal needs.

Modern transport systems place increasing emphasis on effective interaction between carriers, cargo senders, and receivers. The economic success of every transport sector largely depends on its ability to provide reliable, timely, and high-quality transportation services while fully satisfying the needs of businesses and the population. Competition within the national transport market continues to grow, encouraging further modernization and efficiency improvements.

The cargo transportation process itself includes several consecutive stages: preparing goods for shipment, providing rolling stock or vehicles, loading cargo, processing transportation documentation, moving the cargo along the route, unloading, and finally delivering it to the consignee.

The passenger transportation process includes several important stages. First, passenger rolling stock must be prepared and delivered for operation. Transport operators must then ensure safe and convenient boarding conditions for passengers. During the journey, passengers should be provided with an appropriate level of comfort and safety. The final stage involves organizing an efficient and orderly disembarkation process at the destination.

The transportation of passengers and cargo may be carried out using one or several modes of transport. Transportation performed by only one type of transport, such as railway, road, or water transport, is known as direct transportation. When two or more modes of transport are used under a single transport document covering the entire route, this is referred to as direct mixed transportation.

All materials, products, and items accepted for shipment are considered cargo from the moment they are handed over for transportation until they are officially received by the consignee or their representative.

One of the most important indicators of transport efficiency is delivery speed for cargo transportation and connection speed for passenger services. Delivery or connection speed refers to the average speed at which goods or passengers move from the point of departure to the final destination, including all scheduled stops and delays along the route.

Technical speed represents the average speed of a vehicle or rolling stock only during actual movement, without considering stops. Operating speed, also called commercial speed, includes both movement time and all intermediate or terminal stops during transportation.

Several indicators are used to evaluate the technical capacity and development level of different transport systems. These include the total length of transport routes, the number of vehicles in operation, the carrying capacity of the transport fleet, and the availability of maintenance and repair facilities within the transport network.

The capacity of a transport facility or route is defined as the maximum number of vehicles or rolling stock units that can pass through a specific section within a given period under existing technical and operational conditions [5].

Carrying capacity refers to the maximum volume of cargo that can be transported during a certain time period. This depends on factors such as the availability of vehicles, fuel resources, personnel, and other operational assets. In some cases, carrying capacity may also be measured by the number of transport units available for service.

Suburban transportation includes passenger or freight transportation within one region over routes that do not exceed fifty kilometers in length. Intercity transportation, in contrast, covers routes longer than fifty kilometers and may operate both within a single region and between different regions.

Railway transport has several key advantages that make it one of the most efficient and dependable modes of transportation for both passengers and cargo.

1 High carrying capacity: railways can transport large amounts of cargo in a single trip. Freight trains often include dozens of wagons, making them ideal for moving coal, grain, metal, containers, and other bulk goods.

2 Energy efficiency: rail transport consumes less energy per unit of cargo or passenger compared to road and air transport. This is particularly important over long distances, where fuel savings and lower CO_2 emissions are significant.

3 Transportation safety: railways have a lower accident rate than road transport. Modern control and signaling systems help ensure safe train operations and reduce the risk of collisions and other incidents.

4 Environmental friendliness: rail transport is considered one of the most environmentally sustainable forms of transportation, especially on electrified routes. It produces fewer greenhouse gas emissions and air pollutants than road or air transport.

5 Reliability and stability: rail transportation is less affected by weather conditions than road or air travel, which ensures more stable and reliable service throughout the year.

6 Long-distance transportation without transfers: railways allow passengers and cargo to travel long distances without frequent transfers, which is especially beneficial for international transportation.

7 Cost-effectiveness: for large-scale shipments, rail transport is often more economical than air or road transport, particularly on long-distance routes.

8 High throughput capacity: railway networks can handle a large number of trains simultaneously, allowing efficient management of heavy passenger and freight traffic.

9 Transportation of different cargo types: rail transport is suitable for carrying a wide variety of goods, including hazardous, oversized, and heavy cargo. Specialized wagons are used for liquids, bulk materials, vehicles, and other specific loads.

10 Intermodal integration: railways are effectively connected with other forms of transport, including sea, road, and air transport, which supports the development of efficient logistics systems.

The main principles of railway transport organization include several important aspects that ensure efficient, safe, and reliable passenger and freight transportation.

1 Planning and scheduling: clear train scheduling is developed according to track capacity, passenger and cargo demand, and the technical capabilities of locomotives and wagons. Transportation zoning helps separate passenger and freight traffic, improving infrastructure efficiency.

2 Transportation optimization: route planning focuses on the shortest and most economical routes for cargo and passenger movement, reducing transportation time and operational costs. Efficient wagon loading minimizes empty trips and increases productivity.

3 Traffic safety: modern signaling, automation, and protection systems are used to control train movement and reduce accident risks. Regular inspections and maintenance of rolling stock and railway infrastructure help prevent technical failures and emergencies.

4 Coordination and dispatching: centralized dispatch centers monitor train operations in real time, coordinate traffic, and respond quickly to disruptions. Effective communication between stations ensures smooth train arrivals and departures without delays.

5 Flexibility in demand response: railway transport adapts to seasonal changes in passenger and freight traffic, allowing better resource distribution. Additional trains or wagons may be introduced during periods of increased demand or special events.

6 Efficient resource management: locomotives and wagons are distributed according to transportation needs to reduce downtime and improve efficiency. Workforce schedules are organized to maintain continuous operations and comply with labor standards.

7 Intermodal transportation: integration with road, sea, and air transport creates continuous logistics chains and improves delivery efficiency from origin to destination.

8 Contractual relations and tariff policy: transportation services are provided under contracts that define the rights and responsibilities of all parties, ensuring stability and predictability. Transparent tariff systems take into account infrastructure maintenance, labor costs, and operational expenses.

9 Passenger comfort: railway companies improve travel conditions by introducing high-speed trains, onboard catering, internet access, and other modern passenger services.

Timely information: passengers should receive up-to-date information about schedules, delays, transfers, and route changes.

These principles ensure the efficient functioning of railway transport in Ukraine, improve its competitiveness, and strengthen its role within the national transport system:

a) vehicles: rolling stock such as cars, trailers, semi-trailers, transport tractors, wagons, locomotives, aircraft, ships, and helicopters; as well as pipelines, containers, pallets, and tank containers;

b) communication routes: railway tracks, waterways, highways, air routes, monorail systems, and cableways;

c) control and communication systems: dispatch centers and automated traffic management systems;

d) technical equipment and mechanisms: loading and unloading machinery, conveyor systems, and package-forming equipment;

e) buildings and infrastructure: railway stations, depots, service stations, docks, repair workshops, factories, warehouses, bus terminals, airports, piers, compressor stations, and pumping stations [6, 7].

All forms of transport together create a unified transport network that includes ground, underground, air, and water transport. Ground transport includes railway, road, and pipeline transport, as well as modern systems such as magnetic levitation transport, air-cushion transport, monorails, power transmission lines, and cable transport. Underground transport mainly consists of metro systems, water transport includes sea and river navigation, while air transport includes aviation.

Depending on its purpose, transport may be classified as:

Internal transport: transport operating within factories, farms, mines, or quarries to support production processes.

Urban transport: transport serving passengers and cargo within a city.

Suburban transport: transportation between cities and nearby suburban areas within a radius of up to 50 km.

Interregional transport: transportation between neighboring economic regions.

Long-distance transport: transportation over distances greater than 50 km outside populated areas.

International transport: transportation between different countries.

According to organizational subordination, transport can be divided into:

Public transport: transport that is legally required to provide passenger and cargo services to all users.

Departmental transport: vehicles owned and operated by enterprises, institutions, or organizations for internal use.

Increasing attention is being paid to improving cooperation between different transport sectors, cargo senders, and cargo receivers. The economic success of each transport mode depends on its ability to provide timely, reliable, and high-quality transportation services while fully satisfying the needs of businesses and the population. Competition within the transport sector continues to encourage modernization and efficiency improvements.

The cargo transportation process includes cargo preparation, provision of rolling stock, loading operations, documentation processing, cargo movement, unloading, and final delivery to the consignee.

The passenger transportation process includes the preparation of passenger rolling stock, convenient passenger boarding, comfortable travel conditions, and organized passenger disembarkation at the destination.

Transportation may be performed by one or several modes of transport.

Direct transportation: transportation carried out by a single mode of transport such as rail, road, or water.

Direct mixed transportation: transportation involving two or more transport modes under one transport document covering the entire route.

All goods and materials accepted for shipment are considered cargo until they are officially delivered to the consignee.

An important operational indicator for all transport systems is delivery speed for cargo transportation and connection speed for passenger transportation.

Delivery or connection speed is the average speed from the point of departure to the destination, including all scheduled stops.

Technical speed refers to the average speed of rolling stock during movement only.

Operating or commercial speed includes both movement time and intermediate or final stops.

Indicators characterizing the technical level and transport capacity include route length, fleet size, total carrying capacity, and the availability of maintenance and repair facilities.

Transport capacity is the maximum number of vehicles or rolling stock units that can pass through a section within a specific period under existing technical and operational conditions.

Carrying capacity is the maximum volume of cargo that can be transported during a certain period depending on the availability of vehicles, fuel, personnel, and other operational resources.

Suburban transportation includes passenger or cargo transportation within routes not exceeding 50 km.

Intercity transportation includes passenger or cargo transportation on routes longer than 50 km within or between regions.

Railway transport has several important advantages that make it one of the most efficient and reliable forms of transportation.

1 High carrying capacity: freight trains can transport large volumes of cargo, including coal, grain, metal, and containers, in a single trip.

2 Energy efficiency: rail transport consumes less energy per passenger or cargo unit compared to road and air transport, especially over long distances.

3 Transportation safety: advanced signaling and control systems reduce the risk of accidents and improve operational safety.

4 Environmental sustainability: railway transport produces fewer greenhouse gas emissions and pollutants, particularly on electrified rail networks.

5 Reliability and stability: railway operations are less affected by weather conditions than road or air transportation.

6 Long-distance transportation without transfers: railways allow efficient movement of passengers and cargo over long distances without frequent transfers.

7 Cost-effectiveness: rail transportation is often more economical for heavy and large-scale cargo, especially on long routes.

8 High throughput capacity: railway networks can handle large volumes of trains and efficiently manage intensive passenger and freight traffic.

9 Transportation of various cargo types: railways can transport hazardous, oversized, liquid, and bulk cargo using specialized wagons.

10 Intermodal integration: railway transport effectively cooperates with sea, road, and air transport, supporting efficient logistics chains.

Due to these advantages, railway transport remains a vital part of national and international transport infrastructure, ensuring reliable and efficient transportation services.

The main principles of railway transportation organization cover a wide range of measures that ensure efficiency, safety, and reliability in both passenger and freight services.

1 Planning and schedule: clear train movement planning: train timetables are developed based on track capacity, passenger and freight demand, and the technical capabilities of locomotives and wagons. Transportation zoning: dividing time slots for passenger and freight trains helps prevent conflicts on the tracks and improves infrastructure efficiency.

2 Rationalization of transportation: route optimization: selecting the shortest and most cost-effective routes for passengers and cargo reduces time and operational costs. Full train utilization: in freight transport, maximizing wagon and train loading helps reduce empty runs.

3 Traffic safety: signaling and automation systems: modern control technologies such as automatic block systems and safety signaling reduce accident risks and ensure safe movement at crossings. Regular maintenance: systematic inspection and repair of rolling stock and infrastructure help prevent breakdowns and emergencies.

4 Coordination and dispatching: centralized management: dispatch centers monitor train movements in real time, coordinate operations, and respond to emergencies. Station interaction: effective communication between stations

ensures timely processing of arrivals and departures, preventing delays and congestion.

5 Flexibility in demand response: adaptation to seasonal fluctuations: changes in passenger and freight volumes are considered to ensure efficient resource allocation. Additional services: extra trains or wagons are introduced when demand increases or during special events.

6 Efficient resource use: optimal use of rolling stock: locomotives and wagons are distributed according to demand to reduce idle time and support scheduled maintenance. Workforce organization: staff schedules are planned to maintain continuous operation while respecting labor standards.

7 Intermodal transportation: integration with other transport modes: railway transport is organized as part of a continuous logistics chain using road, sea, and air transport to ensure smooth delivery from origin to destination.

8 Contractual relations and tariff policy: contractual regulation: all transportation is carried out under agreements defining the rights and responsibilities of the parties, ensuring stability and predictability. Transparent pricing: tariffs are set clearly and reasonably, taking into account infrastructure maintenance, labor costs, and operational expenses.

9 Passenger comfort: service improvement: modern passenger services include high-speed trains, onboard internet access, and catering services. Timely information: passengers are provided with up-to-date details about schedules, delays, and transfer options.

These principles ensure the effective functioning of railway transport in Ukraine, enhancing its competitiveness and reinforcing its role as a key element of the national transport system.

Check questions

1 What is the main purpose of studying the discipline “Management of the railway transport system”?

2 When and where was the first railway on the territory of modern Ukraine built?

3 What are the main components of transport systems?

4 What are some important advantages of railway transport?

5 Why is planning and scheduling important in railway transportation?

Lecture 2

STRUCTURE OF RAILWAY TRANSPORT MANAGEMENT. COMPLEX OF STRUCTURES AND DEVICES OF RAILWAY TRANSPORT. DIMENSIONS ON RAIL TRANSPORT. GENERAL CONCEPTS. TYPES OF DIMENSIONS AND AREAS OF THEIR APPLICATION. DISTANCES BETWEEN RAILROAD TRACKS. OVERSIZED CARGO AND CONDITIONS OF ITS TRANSPORTATION

Structure of railway transport management in Ukraine.

Railway transport is a key sector of Ukraine’s transport system, responsible for passenger and freight transportation both domestically and internationally. Its management is organized as a multi-level system that ensures coordination, safety, and efficiency of railway operations [1].

1 Ministry for Development of Communities, Territories and Infrastructure of Ukraine: this is the central executive authority responsible for forming and implementing state policy in the field of transport, including railways. It defines the strategic development of railway infrastructure, regulates the legal framework, and oversees international cooperation in the transport sector [1].

2 Joint Stock Company “Ukrainian Railways” (Ukrzaliznytsia): the unified state railway operator that carries out centralized management of public railway transport in Ukraine. It is responsible for passenger and freight transportation, infrastructure maintenance, as well as modernization and repair of rolling stock. The company operates under the leadership of its Chief Executive Officer and has a structured corporate management system. Operational activities are organized through regional branches that replaced the former railway directorates [8].

Ukrzaliznytsia manages six regional branches that cover the entire railway network of the country: Lviv Railway, South-Western Railway, Odesa Railway, Southern Railway, Dnipro Railway, Donetsk Railway [8].

Each regional branch is responsible for organizing train operations within its territory, maintaining railway tracks and stations, and coordinating the work of depots and other infrastructure units.

A regional branch is the basic structural unit of railway transport that operates within a defined part of the national railway network. It is responsible for organizing transport services for passengers and freight, as well as carrying out operational and commercial activities aimed at efficient functioning of the railway system.

The main functions of a regional branch include:

Ensuring the reliable and timely movement of passengers and cargo within its service area, including the use of railway infrastructure and related services.

Maintaining a high level of operational safety in train movements, as well as ensuring safe working conditions for railway personnel [21].

Guaranteeing the safety and well-being of passengers throughout all stages of rail transport services.

Expanding and improving transport services to meet the needs of different categories of users, regardless of ownership or sector.

Supporting the development of technical infrastructure and improving the material base of the railway system.

Keeping railway infrastructure, equipment, and technical facilities in proper operational condition to ensure uninterrupted transport processes.

Implementing environmental protection measures to reduce the negative impact of railway operations.

Maintaining readiness of technical and emergency services to respond quickly to accidents or unforeseen situations [9].

In Ukraine, railway operations are coordinated by "Ukrzaliznytsia", which includes several regional branches responsible for different parts of the national network: Lviv Railway, South-Western Railway, Odesa Railway, Southern Railway, Dnipro Railway, Donetsk Railway.

Each of these branches manages transportation processes within its territory, ensures the functioning and maintenance of railway infrastructure, and oversees the operation of depots, stations, and other technical units.

A regional branch is the main operational unit within railway transport, responsible for organizing passenger and freight services in a defined section of the railway network. It also carries out production and commercial functions aimed at ensuring efficient performance and financial results.

The key tasks of a regional branch include the following.

Timely and high-quality organization of freight and passenger transport, as well as provision of services related to the use of railway infrastructure and facilities to meet transport needs within its territory.

Ensuring safe train operations and maintaining occupational safety standards for railway employees.

Guaranteeing the protection of life and health of passengers using railway transport services.

Expanding and improving the range of transport services available to all users, regardless of ownership or type of activity.

Strengthening the material and technical base of the railway system and supporting its social development.

Keeping railway infrastructure, equipment, and technical systems in proper working condition to ensure uninterrupted transport operations.

Protecting the environment by reducing pollution and other negative impacts caused by railway activities.

Ensuring readiness of emergency and technical response units to handle accidents and critical situations [9].

There are various departments within the railway sector responsible for the functioning and coordination of different areas of the railway system. Below is a brief description of each:

Transportation Department responsible for organizing and regulating train operations, including scheduling, timetable coordination, and interaction between railway units. It is headed by the Chief of the Transportation Department.

Commercial Department responsible for tariff policy, contractual relations, freight organization, and customer service activities. It is managed by the Chief of the Commercial Department.

Passenger Department responsible for passenger transport services, station operations, service quality, and overall passenger experience. It is led by the Chief of the Passenger Department.

Signaling and Communications Department responsible for maintaining signaling systems and communication networks that ensure safe train operations. It is headed by the Chief of the Signaling and Communications Department.

Electricity Supply Department responsible for powering railway infrastructure, maintaining electrical networks, and managing substations. It is managed by the Chief of the Electricity Supply Department.

Locomotive Department responsible for the operation, maintenance, and repair of locomotives. It is led by the Chief of the Locomotive Department.

Track Department responsible for maintaining, repairing, and ensuring the technical condition of railway tracks for safe operation. It is headed by the Chief of the Track Department.

Wagon Department responsible for the technical condition, maintenance, and repair of freight and passenger wagons. It is managed by the Chief of the Wagon Department.

Financial and Economic Department responsible for budgeting, financial management, and analysis of revenues and expenditures. It is headed by the Chief Financial Officer or department head.

Capital Construction and Civil Engineering Department responsible for constructing new railway facilities and modernizing existing infrastructure. It is led by the Chief of the Capital Construction Department.

Human Resources Department responsible for recruitment, staffing, training, and professional development of employees. It is headed by the Chief of the Human Resources Department.

Fire Safety Department responsible for fire prevention measures and ensuring safety at railway facilities. It is managed by the Chief of the Fire Safety Department.

Occupational Safety Department responsible for workplace safety, compliance with safety regulations, and prevention of occupational injuries. It is headed by the Chief of the Occupational Safety Department.

Statistics and Economic Analysis Department responsible for data collection, operational analysis, and preparation of statistical reports. It is managed by the Chief of the Statistics and Economic Analysis Department.

Legal Department responsible for legal support, documentation, and representation in legal matters. It is headed by the Chief of the Legal Department.

Special Department responsible for security-related tasks and protection of critical railway facilities. It is managed by the Chief of the Special Department.

Medical Department responsible for healthcare services for employees, medical examinations, and preventive health measures. It is headed by the Chief of the Medical Department.

Material and Technical Supply Department responsible for providing materials, equipment, and technical resources required for railway operations. It is managed by the Chief of the Material and Technical Supply Department.

These department heads are typically subordinate to the Chief of Railway Transport or the Director of the respective regional branch, which is responsible for railway operations within a specific region [9].

Wagon Depots (WD), Locomotive Depots (LD), Track Sections (TS), Signaling and Communications Sections (SCS), and Electricity Supply Sections (ESS) are separate structural units within the railway system.

These units function as independent operational divisions within the overall railway structure and are responsible for specific technical and production tasks. Each unit has its own management, reports to the relevant higher services, and ensures the maintenance and servicing of railway infrastructure:

Wagon Depots (WD) responsible for the maintenance and repair of wagons, ensuring their technical reliability and safe operation on the railway network.

Locomotive Depots (LD) responsible for the maintenance, repair, and operation of locomotives, as well as the training and preparation of locomotive crews.

Track Sections (TS) responsible for maintaining and repairing railway tracks, including rails, sleepers, and supporting infrastructure, ensuring their safe technical condition.

Signaling and Communications Sections (SCS) responsible for the maintenance and operation of signaling systems and communication networks that ensure safe and coordinated train movement.

Electricity Supply Sections (ESS) responsible for providing and maintaining electrical power systems, including substations and power lines that support railway operations.

These units operate independently within the railway system but closely cooperate with each other to ensure continuous and uninterrupted transport operations [3].

Functional branches and units of JSC “Ukrzaliznytsia”

In addition to regional branches, Ukrzaliznytsia includes several functional divisions responsible for specific operational areas:

Passenger Company Branch responsible for organizing passenger transport, developing services, and managing passenger trains and stations.

Lisky Branch responsible for container transportation and logistics operations.

Transport Logistics Center Branch responsible for freight transportation management and coordination with clients.

Energy Supply Branch responsible for maintenance and modernization of railway power supply systems.

Railway Automation and Communications Branch responsible for signaling systems, communication networks, and automated train control systems [8].

Railway Directorates in Ukraine

Railway directorates in Ukraine are structural units within JSC “Ukrzaliznytsia” responsible for managing specific sections of railway infrastructure and operational activities. Although the railway system is currently organized under a centralized management model, regional directorates continue to play an important role in ensuring effective day-to-day operations [8].

The main tasks of the directorates include the following.

Timely and high-quality execution of passenger, freight, baggage, and mail transportation, as well as providing access to railway infrastructure and related services to meet transportation needs within the assigned region. They also ensure the safe organization of train movements, compliance with schedules, and protection of transported cargo [9].

Key documents regulating railway operations

Railway Statute: this is a fundamental legal document that defines the rights and obligations of railway operators and service users. It regulates contractual relations, transportation procedures for passengers, freight and luggage, and interaction between different modes of transport, serving as the main legal framework for railway services.

Rules for Freight Transport: these rules establish mandatory requirements for loading, transportation, and unloading processes. They regulate the technological procedures of freight handling and ensure safety, consistency, and efficiency in cargo operations [6].

Rules for Technical Operation of Railways (RTOR): this document defines the technical standards for the operation of railway infrastructure, rolling stock, and related equipment. It regulates train movement organization, signaling systems, and safety procedures, which are essential for safe railway operations [7].

Complex of Railway Transport Structures and Devices.

The railway transportation process is carried out using a wide range of technical means, including rolling stock, infrastructure, and specialized equipment.

The complex of railway transport structures and devices consists of:

Main railway tracks and artificial structures required for their construction and stable operation.

Developed track layouts at stations and other junction points used for receiving and dispatching trains, overtaking, crossing, forming and splitting train sets, sorting wagons, and performing other operational tasks.

Facilities, equipment, and high-performance machinery used for the construction, maintenance, and repair of railway tracks.

Devices for receiving, dispatching, storing, loading, and unloading cargo.

Passenger facilities designed for boarding, alighting, and servicing passengers.

Automation, telemechanics, communication, and computing systems that ensure safe train movement and efficient management of operational processes.

Infrastructure for maintenance, servicing, and repair of locomotives and wagons.

Electric power supply systems, including traction substations and overhead contact networks on electrified railways.

Heat and water supply systems supporting railway operations and facilities.

Material and technical supply systems responsible for providing resources and equipment necessary for railway functioning [3, 4].

Dimensions on railway transport. General concepts, types and application.

For safe train operation, it is essential that locomotives and freight wagons move freely along railway tracks without contacting nearby structures, devices, or rolling stock on adjacent tracks. This requirement is ensured through strict compliance with established structure clearance dimensions, rolling stock dimensions, and loading gauge standards, which apply to both public railway networks and industrial sidings.

There are three main types of railway dimensions: structure clearance gauge, rolling stock gauge, and loading gauge [10].

Structure clearance gauge defines the boundary contour perpendicular to the track axis within which no part of railway structures or fixed installations is allowed to extend. Exceptions are made only for devices that directly interact with rolling stock, such as working car retarders, contact wires with fittings, or rotating parts of water supply systems during operation.

Rolling stock gauge represents the maximum external outline within which both loaded and empty railway vehicles must remain when positioned on a straight, level track without exceeding the boundary.

Loading gauge defines the maximum permissible outline of cargo (including packaging and fastening elements) placed on open wagons, ensuring that the load does not extend beyond the allowed limits during transportation on straight track sections.

The structure clearance gauge C is applied on the general railway network and on external industrial sidings from junction stations to industrial and transport enterprises. It is used in the construction of new lines, addition of second tracks, electrification projects, and reconstruction of railway infrastructure.

The gauge Sn differs from gauge C by a reduced height of 5500 mm, and inside buildings it is 5400 mm. It is used within industrial areas, freight yards, warehouses, and other transport and production facilities.

Compliance with structure clearance dimensions is monitored using inspection methods such as a control platform equipped with a special wooden frame, whose outer contour corresponds to gauge C or Cn, moving along the railway track to verify clearance accuracy [10].

The distances between the axes of adjacent tracks are determined by the conditions of train traffic safety and personal safety of the personnel located between the tracks. This takes into account the relevant dimensions of the rolling stock and the proximity of structures.

According to the Rules of Technical Operation, the distance between the track axes on straight sections of two-track races should be at least 4100 mm. On three- and four-track sections, the distance between the axes of the second and third tracks on straight sections must be at least 5000 mm

Such an increase allows for the necessary track tools to be left in this space between the tracks, as well as for the installation of appropriate signal signs, while ensuring the unimpeded passage of trains.

Distances between the axes of adjacent tracks at stations, junctions and overtaking points should be no less than this:

- on the main, receiving, sending and sorting tracks – 4800 mm (a distance of 5300 mm is considered normal);

- on secondary tracks and tracks of cargo areas – 4500 mm;

- in receiving and departure parks, where uncoupled car repair is provided – 5600 and 5300 mm across one track;

- on tracks intended for direct transshipment of goods from car to car – 3600 mm.

When the speed of trains on double-track lines exceeds 120 km/h, the distance between the axes of the main and adjacent tracks should be at least 6500 mm [7].

On curved sections, the distance between the track axes should be greater, because here the end parts of the rolling stock go outside the curve, and the central part of the cars, on the contrary, is shifted inside the curve. In addition, the outer rail is installed higher than the inner rail, and the rolling stock leans toward the center of the curve.

Due to these circumstances, on curved sections, the horizontal distances between the axes of adjacent tracks, as well as between the axis and the approach gauge of structures both on tracks and at stations, are larger and are determined by the above-mentioned Instruction on the application of approach gauges of structures.

The compliance of loaded open rolling stock with the specified size is checked at places of mass loading (on sidings, in sea and river ports, at transshipment stations) using dimensional gates. Such a device is a frame with slats hinged inside it along the contour of the load size. If a loaded railcar passes through the gate without touching the slats, the dimension is met [10].

In justified cases, railroads also carry out transportation with the use of increased loading dimensions. The zonal gauge is used in areas of mass transportation of timber in gondola cars. It has an increased width in the upper part. Due to the additional loading of cars with the same number of rolling stock, a much larger volume of transportation is carried out.

The preferential loading dimension, which is 3400 mm wide at the floor level of the universal platform, is used for the transportation of large-sized equipment, such as agricultural machinery loaded on its own wheels. This helps to dramatically reduce the time and labor costs associated with loading and unloading, and thanks to the quick redeployment of equipment, prevent crop losses during harvest [5].

Rail transport also carries out transportation of oversized cargo, the dimensions of which (including packaging and fasteners) exceed the dimensions of the load. Transportation of oversized cargo is carried out in accordance with the Instruction approved by the Ministry of Infrastructure under the special train schedule [11].

Special train traffic procedure: this includes enhanced control over transportation, special route planning, and other safety measures.

Information of the personnel involved: it is essential to ensure that all staff participating in the transportation of oversized cargo are properly informed about the specific requirements of the operation.

Speed limits: to ensure safety during the transportation of oversized cargo, speed restrictions may be introduced.

Restriction of traffic on adjacent tracks on double-track sections: to prevent potential risks during the movement of oversized cargo, traffic on neighboring tracks may be temporarily limited.

Passage along pre-prepared routes at stations: pre-planned routes ensure safe and efficient movement of trains through station areas.

Depending on the height at which cargo exceeds the loading gauge, several oversize zones are defined.

Depending on the degree to which cargo exceeds loading dimensions, the following levels of oversize are established within these zones: lower oversize includes six degrees, side oversize includes six degrees, and upper oversize includes three degrees.

Cargo that exceeds the boundary contours of oversize zones or the loading gauge in the lower (below 480 mm) or upper (above 5300 mm) limits is classified as oversized cargo [12].

Oversized cargo transportation in railway operations is carried out under special safety conditions in accordance with established railway regulations of Ukraine. Cargo classified as oversized, including lower and lateral oversize of the 6th degree, is transported under enhanced control using a clearance control frame installed on a separate wagon.

In such cases, the wagon carrying the oversized cargo is placed in the train formation at a safe distance from the locomotive, typically separated by at least one empty platform wagon. The wagon with the cargo is usually positioned not closer than 20 wagons from the wagon equipped with the control frame to ensure safe monitoring of clearance conditions along the route [12].

A railway employee accompanying the cargo is located in the rear cab of the locomotive or in a designated observation position and is responsible for monitoring the passage of the control frame through all potentially hazardous sections. In case the control frame comes into contact with any structure or obstacle, the accompanying person must immediately inform the locomotive crew so that necessary operational measures can be taken.

Safe storage distances near railway tracks must also be strictly observed. Materials and cargo placed near the track for loading or unloading must be arranged and secured in such a way that they do not violate the structure clearance envelope and do not interfere with train movement.

Cargo with a height of up to 1.2 meters must be stored at a distance of at least 2.0 meters from the outer edge of the nearest rail head. For cargo exceeding 1.2 meters in height, the minimum distance must be increased to at least 2.5

meters. These requirements do not apply to ballast materials that are specifically placed during track construction or repair works.

Check questions

1 What is the role of the Ministry for Development of Communities, Territories and Infrastructure of Ukraine in railway transport management?

2 What are the six regional branches of JSC "Ukrzaliznytsia"?

3 Which department is responsible for train safety, signaling, and communication systems?

4 What are the main functions of Wagon Depots (WD) and Locomotive Depots (LD)?

5 What is the difference between the structure gauge, rolling stock gauge, and loading gauge?

Lecture 3
TRACK FACILITIES. STRUCTURE OF THE TRACK FACILITIES. TRACK ARRANGEMENT AND REGULATORY REQUIREMENTS FOR ITS MAINTENANCE. TRACK STRUCTURES. LOWER AND UPPER TRACK STRUCTURE. NORMS AND REQUIREMENTS FOR TRACK CONDITION AND ITS ASSESSMENT. TYPES AND FREQUENCY OF REPAIRS. TRACK DISTANCES AND TECHNOLOGY OF THEIR WORK. TRACK MACHINE STATIONS AND TECHNOLOGY OF THEIR WORK. MAIN INDICATORS AND CURRENT STATE OF TRACK FACILITIES.

The railway track is a complex engineering structure designed to withstand heavy dynamic loads from moving trains. It ensures the safe and continuous operation of all types of trains at established speeds under varying climatic and weather conditions.

The condition of the railway track has a direct impact on traffic safety, the efficient use of rolling stock and technical equipment, as well as the overall economic performance and competitiveness of railway transport [13].

Railway infrastructure includes the track itself with all adjacent structures and technical devices, as well as a complex of production and operational units responsible for its maintenance, repair, and uninterrupted functioning. These units ensure scheduled preventive maintenance and reliable operation of all technical systems [14].

The railway track consists of two main parts: the substructure (lower structure) and the superstructure (upper structure).

The substructure includes the railway foundation, which may be constructed in the form of an embankment, cut, semi-cut, or semi-embankment. It also includes artificial engineering structures such as bridges, tunnels, viaducts, overpasses, dams, and similar facilities that ensure the stability and continuity of the track.

A key characteristic of the subgrade is the steepness of its slopes, which describes the relationship between the vertical height of the slope and its horizontal extension. In other words, it shows how many units of horizontal distance correspond to one unit of vertical rise. This relationship expresses how “steep” or “gentle” the slope is.

The most common slope configuration used in railway construction is the 1:1.5 ratio, which is referred to as a “one-and-a-half slope.” This means that one unit of vertical height corresponds to one and a half units of horizontal distance, which ensures better stability and resistance of the embankment.

The subgrade must meet strict engineering requirements. It must be strong enough to carry heavy loads, stable under natural influences, reliable in long-term operation, and durable throughout its service life.

All surfaces of the subgrade and all devices located within the railway right-of-way must be designed and maintained in such a way that atmospheric water does not accumulate in any area. Maximum drainage must be ensured either toward the sides or into dedicated drainage systems, while surface water must not cause erosion of slopes or damage to the subgrade foundation.

The design of the subgrade structure must ensure minimum construction and maintenance costs while allowing the highest possible level of mechanization during construction, repair, and maintenance works.

The upper structure of the railway track consists of the ballast layer, rails, sleepers, rail fastenings, anti-creep devices, switches, and other track components. The ballast layer forms a ballast prism that absorbs loads from the sleepers and distributes them evenly onto the subgrade. According to current technical standards of Ukrzaliznytsia, crushed stone ballast is used for mainline tracks of all categories [13, 3].

Rails and sleepers, connected through fastening systems, form a single structural unit called the rail-sleeper grid. This structure directly receives dynamic loads from rolling stock wheels and transfers them to the ballast layer. The rigid fastening system maintains the fixed position of the rails and ensures that the distance between the inner edges of the rail heads remains within established limits.

On straight track sections, the standard rail gauge is 1,520 mm, with permissible deviations of +8 mm and −4 mm. As a result of the interaction of all elements of the upper structure, loads from rolling stock are transferred to the subgrade in a relatively uniform manner, typically within the range of approximately 80–100 kPa.

Rail fastenings are designed to securely connect rails both to each other and to sleepers, ensuring stability of the track geometry under dynamic loads.

The upper structure operates under complex conditions, being exposed to repeated dynamic loads from train traffic, atmospheric precipitation, wind, and temperature fluctuations. Despite these influences, it must maintain sufficient strength, stability, durability, and economic efficiency.

The type of upper track structure is primarily determined by rail strength and depends on freight intensity, axle loads, and train speeds. According to freight traffic volume, railway mainlines are divided into different categories, and the corresponding type of track structure is selected for each category.

Railway upper track structure is classified into three types: Extra Heavy, Heavy, and Normal, depending on freight intensity and structural parameters.

The Extra Heavy type is used for freight intensity over 88 million ton-km gross per km per year; it uses R75 rails and wooden sleepers, with a ballast layer thickness of 55 cm, ballast prism shoulder length of 45 cm, and ballast prism width at the top of 3.6/7.7 cm.

The Heavy type is designed for freight intensity from 15 to 80 million ton-km gross per km per year; it uses R65 rails with wooden or reinforced concrete sleepers, a ballast layer thickness of 50 cm, shoulder length of 35 cm, and width at the top of 3.4/7.5 cm.

The Normal type is used for freight intensity up to 15 million ton-km gross per km per year; it uses R50 rails with sleepers of the same type, a ballast layer thickness of 45 cm, shoulder length of 25 cm, and width at the top of 3.2/7.3 cm.

When reinforced concrete sleepers are used, the total ballast layer thickness is increased by 5 cm, with crushed stone or asbestos used as ballast material, and the values for single-track lines are given in the numerator while double-track lines are indicated in the denominator.

The main function of the ballast layer is to receive pressure from sleepers and distribute it evenly onto the subgrade, ensuring stable support of the track structure under vertical and horizontal loads. It also provides elasticity to the track bed, enables adjustment of the rail-sleeper grid in both plan and profile, and ensures effective drainage of surface water away from the track.

The ballast layer must not retain water on its surface and should protect the subgrade from excessive moisture. The material used for ballast must be strong, elastic, resistant to mechanical loads and weather conditions, and economically efficient. It should not degrade under compaction, generate dust under train movement, be blown away by wind, washed out by rain, or support vegetation growth.

Loose, well-draining materials with good elasticity are used as ballast, including crushed stone, gravel, sand, slag, and shell rock. On mainline tracks, crushed stone with a grain size of 25–60 mm is most commonly used, while lower-traffic lines may use gravel, blast furnace slag, or sand. The most suitable ballast material is crushed stone produced from hard natural rock.

During operation, ballast becomes contaminated, which reduces its drainage capacity and overall performance. Therefore, crushed stone ballast is periodically cleaned, while gravel and sand ballast is replaced or replenished. To improve durability and reduce maintenance costs, modern practice may include treating crushed stone with binding polymer materials to increase stability.

To reduce ballast contamination and prevent cargo losses during transportation, it is prohibited to load bulk materials into wagons with damaged floors or doors. It is also not allowed to load coal in a way that allows it to form unstable coverings that may be blown away or spill onto the track. In addition, special protective solutions may be applied to bulk cargo after loading to form a surface film that prevents material loss during movement.

Sleepers are the main element of the under-rail support system. Their function is to receive loads from the rails and transfer them to the ballast layer, while also maintaining rail position and ensuring track gauge stability. The under-rail structure may also include bridge beams, transition beams, half-sleepers, slabs, and frame-type supports [14].

Sleepers must be strong, elastic, durable, cost-effective, and resistant to electrical currents. Sleeper density, meaning the number of sleepers per kilometer of track, typically ranges from 1,440 to 2,200 units per kilometer, while in Ukrainian railway practice it is generally 1,840 to 2,000 units per kilometer.

Sleepers are made from wood, reinforced concrete, or steel. On most modern mainlines worldwide, reinforced concrete sleepers are used together with heavier rail types. Wooden sleepers are still used on less intensive lines where high speeds are not required, while steel sleepers are rare and used in specific conditions.

Approximately 90 % of sleepers worldwide are wooden and impregnated with protective oil-based substances. Their advantages include relatively low weight, elasticity, ease of manufacturing, convenient rail fastening, and good electrical insulation properties. However, their disadvantages include a limited service life of about 15–18 years and high consumption of valuable timber resources.

Common wood species used for sleepers include pine, spruce, fir, and larch, while beech and birch are used less frequently.

Wooden sleepers are manufactured in two main types according to their cross-sectional shape: planed type A, which is planed on all four sides, and block type B, which is planed only on the upper and lower surfaces. This classification allows the use of logs with different diameters in production. Both types are further divided into three categories: Type I for main railway lines, Type II for station tracks and sidings, and Type III for industrial tracks. The standard length of wooden sleepers is 2,750 mm, while sleepers of 2,800 mm are used in sections with increased load requirements.

Reinforced concrete sleepers with prestressed reinforcement are widely used in modern railway systems. Their main advantages include a long service life of 40–50 years, high track stability, and smooth train movement due to uniform geometry and structural rigidity. They also contribute to the conservation of timber resources by replacing wooden sleepers in large-scale railway networks, including high-speed lines.

Their disadvantages include high mass, electrical conductivity, increased rigidity, and more complex rail fastening systems. To improve track elasticity, elastic pads are installed between the rail and sleeper. To prevent electrical conductivity issues, insulating elements are integrated into the fastening systems.

In metro systems and depot inspection pits, half-sleepers embedded in concrete are used instead of full sleepers.

Rails are designed to guide wheel movement, transfer vertical and horizontal loads to sleepers, and ensure stable train operation. In addition, they serve as conductors of signal current in automatic block systems and as return conductors for traction current in electrified railways.

Rails must possess high strength, durability, wear resistance, hardness, and sufficient toughness, since they are subjected to repeated impact-dynamic loads. They are manufactured from high-strength carbon steel. Depending on their mass and cross-sectional characteristics, rails are classified into types R50, R65, and R75, where the number indicates the approximate weight of one meter of rail in kilograms. Earlier, R43 rails were also used on railway networks until 1962.

The most rational rail profile is the I-shaped section, as it provides optimal resistance to bending under vertical loads while reducing material consumption.

The selection of rail type depends on line capacity, axle loads, and train speeds. For high-speed passenger lines, R65 rails are commonly used. The standard rail length is 25 meters. Shorter rails (24.92 m and 24.84 m) are produced for use in curves. For continuous welded rail sections and switch areas, shorter standard rails of 12.5 m and additional lengths (12.46 m, 12.42 m, and 12.38 m) are also used for precise adjustment during installation.

The service life of rails is determined by the total tonnage of traffic that has passed over them. On average, thermally strengthened R65 rails are replaced after approximately 500 million gross tons of traffic, while R50 rails reach about 350 million gross tons before replacement. The service life of R75 rails is roughly 30 % longer than that of R65 rails.

Extending rail service life is achieved through a set of interconnected measures. These include increasing rail mass, improving the quality of rail steel, applying thermal strengthening processes, optimizing rail cross-sectional design, improving operating conditions through the use of continuously welded rail, regular grinding of the running surface, and lubrication of the gauge face in curves. In addition, maintenance strategies such as timely replacement of defective rails and redistribution of rail elements from reserve stock are applied. For this purpose, a kilometer reserve of rails is stored at designated points along each track section.

A railway track consists of two continuous rail lines maintained at a fixed distance from each other. This is ensured by fastening rails to sleepers and joining individual rail sections into continuous strings. Intermediate rail fastenings provide a secure and elastic connection between rails and sleepers, maintain track gauge stability, ensure correct rail inclination, and prevent longitudinal and lateral displacement. When reinforced concrete sleepers are used, these fastenings must also provide electrical insulation between the rail and the sleeper.

Intermediate fastenings are generally divided into three types: non-separable, mixed, and separable.

In non-separable fastenings, rails and supporting baseplates are fixed to sleepers using the same fastening elements such as spikes or screws. In mixed fastenings, baseplates are additionally secured to sleepers using extra fasteners. The mixed spike fastening system with wedge-shaped baseplates and a 1:20 inclination is widely used on railway networks. Its advantages include simple design, low weight, and relatively easy installation, adjustment, and removal. However, it does not always ensure stable gauge retention and may lead to increased wear of sleepers.

The most effective way to prevent rail longitudinal movement (track creep) is the use of crushed stone ballast combined with separable fastenings, which provide sufficient resistance to longitudinal forces without the need for additional securing devices. In non-separable and mixed fastening systems, anti-creep devices are used.

Track creep refers to the gradual longitudinal displacement of rails relative to sleepers caused by dynamic loads from passing trains and temperature variations. It can occur on any section of track but is most common on gradients and braking zones.

Standard anti-creep devices are usually spring-type and consist of a spring clamp that grips the rail base and presses against the sleeper. Self-locking anti-creep devices include a clamp and wedge mechanism that increases locking force as rail movement occurs, providing enhanced resistance to longitudinal displacement.

Types and frequency of track repairs

Railway track maintenance is carried out through a system of planned repairs and preventive works. The main types include current maintenance, medium repair, and capital repair [15].

Current maintenance is performed regularly during operation and includes inspection of the track, tightening of fastenings, correction of minor defects, cleaning of ballast, and maintaining geometry.

Medium repair is carried out periodically and includes partial replacement of sleepers and rails, ballast cleaning or renewal, and restoration of track geometry and drainage conditions.

Capital repair is the most extensive type of repair and involves complete renewal of rail-sleeper grid, ballast replacement, and restoration of the subgrade where necessary. It is performed after reaching the established wear limits of the track structure.

The frequency of repairs depends on traffic intensity, axle loads, train speeds, and overall condition of the track.

Track machine stations (PMS) are specialized production units responsible for mechanized maintenance and repair of railway tracks. They are equipped with heavy track machinery such as tamping machines, ballast cleaners, rail-laying cranes, and alignment systems [15].

Their main function is to perform large-scale repair works using mechanized technology, which significantly increases productivity and ensures higher accuracy of track geometry restoration. PMS units operate according to planned schedules and are deployed to sections of track requiring repair or reconstruction.

Main indicators of track condition

The technical condition of railway tracks is assessed using several key indicators. These include track geometry parameters (gauge, alignment, and level), smoothness of running surface, condition of rails and fastenings, quality of ballast support, and overall stability of the track structure.

Additional indicators include permissible speed levels, ride comfort for passengers, degree of wear of rail elements, and frequency of required maintenance interventions. Regular monitoring of these parameters ensures safe and efficient operation of railway transport [16].

Check questions

1 What are the two main parts of a railway track structure?

2 What is the main purpose of the ballast layer in railway tracks?

3 What materials are commonly used for railway sleepers?

4 What do the rail types R50, R65, and R75 mean?

5 What is “track creeping” and how is it prevented?

Lecture 4

POWER SUPPLY OF RAILWAYS. POWER SUPPLY OF ELECTRIFIED RAILWAYS. CURRENT SYSTEM AND VOLTAGE ON RAILWAYS. TRACTION SUBSTATIONS. TRACTION SUBSTATION OF ALTERNATING CURRENT. TRACTION SUBSTATION OF DIRECT CURRENT. CONTACT NETWORK, DIMENSIONS OF SUSPENSION AND INSTALLATION OF SUPPORTS. POWER SUPPLY OF SIGNALING AND CONTROL DEVICES AND PROTECTION OF UNDERGROUND STRUCTURES. DOCKING OF DIFFERENT ELECTRIC TRACTION SYSTEMS

The power supply system of railway transport is a key component of electrified railways, ensuring reliable and uninterrupted operation of electric traction rolling stock, signalling and communication systems, as well as auxiliary railway facilities. In Ukraine, the principles of railway electrification and power supply are regulated by the Technical Operation Rules of Railways and relevant standards of Ukrzaliznytsia, which define requirements for safety, reliability, and continuity of energy supply [3, 4].

Power supply of electrified railways is organized as a complex system that includes external power sources, traction substations, contact networks, and return current circuits through rails. Electrical energy is supplied from the national power grid to traction substations, where it is converted and distributed to the contact network supplying electric rolling stock [14].

The railway power system must ensure stable voltage levels, minimal energy losses, and high reliability under varying load conditions caused by train traffic intensity [17].

On the railways of Ukraine, two main systems of electric traction are used: direct current (DC) and alternating current (AC).

The direct current system typically operates at a nominal voltage of 3 kV. It is widely used on older electrified lines and in dense traffic areas.

The alternating current system operates at a voltage of 27.5 kV with a frequency of 50 Hz. It is applied on modernized main lines due to its higher efficiency in long-distance power transmission and reduced energy losses.

The choice of current system depends on traffic density, line category, and technical-economic feasibility of electrification projects.

Traction substations are electrical installations that convert and distribute electrical energy for supplying the contact network of railways. They are key elements of the power supply system and are located along electrified lines at defined intervals to ensure stable voltage levels.

Their main functions include: transformation of high-voltage electricity from the national grid; conversion of alternating current to direct current (where required); distribution of traction energy to contact networks; protection of power systems from overloads and short circuits.

Traction substations are designed to operate under high load conditions and are equipped with modern automation and protection systems.

AC traction substations receive high-voltage three-phase alternating current from the power system and reduce it using step-down transformers to the required traction voltage of 27.5 kV. The energy is then supplied directly to the contact network.

These substations are equipped with switching devices, circuit breakers, and relay protection systems to ensure stable operation and quick isolation of faults. AC substations are characterized by higher efficiency, reduced number of substations along the line, and lower transmission losses.

DC traction substations convert high-voltage alternating current from the external grid into direct current using rectifier units. The output voltage of 3 kV is supplied to the contact network.

Such substations include transformer-rectifier units, smoothing reactors, and protective equipment. DC systems require a larger number of substations due to higher energy losses in the contact network, but they provide smooth acceleration and stable traction characteristics for rolling stock.

The contact network is a complex technical system of overhead conductors and supporting structures designed to supply electrical energy from traction substations directly to electric rolling stock during movement. It is one of the most critical elements of electrified railways, as it ensures continuous energy transfer under dynamic operating conditions. The contact network includes several interrelated components: the contact wire that directly interacts with the current collector (pantograph), the messenger wire that supports the contact wire mechanically, suspension and tensioning devices, sectional insulators, and supporting structures such as poles, portals, and foundations.

In accordance with the Technical Operation Rules of Railways of Ukraine, the contact network must provide stable and uninterrupted current collection under all operating conditions, including high-speed train movement, vibration, wind loads, temperature variations, and icing conditions. The design of the suspension system is based on maintaining optimal elasticity and geometric stability of the contact wire, which prevents loss of contact with the pantograph and reduces wear of both the wire and current collectors.

The geometric parameters of the contact network are strictly standardized. The height of the contact wire above the rail head is regulated depending on the category of line, type of rolling stock, and operating conditions. It must remain within permissible limits to ensure safe clearance for all types of rolling stock, including oversized loads, while maintaining reliable electrical contact. In addition, the lateral displacement (zigzag arrangement) of the contact wire relative to the track axis is designed to ensure uniform wear of the pantograph contact strips and stable current collection when the train is moving at high speed or under crosswind influence.

The installation of contact network supports is carried out based on detailed engineering calculations that take into account track alignment, curvature, gradient, permissible span length, mechanical tension of wires, and environmental factors such as wind pressure and ice loading. Supports are typically made of reinforced concrete or metal structures and are installed at calculated intervals to ensure uniform mechanical load distribution across the entire line.

Special attention is given to the foundation stability of supports, especially in areas with weak soil conditions or high dynamic loads. On curves, at stations, and at complex engineering structures such as bridges and tunnels, the placement of supports is adjusted to ensure safe clearance and reliable operation of the contact system.

Overall, the contact network system must ensure high operational reliability, minimal maintenance requirements, and long service life while maintaining stable energy supply conditions for electrified railway transport.

Power supply of signalling and control devices and protection of underground structures.

Railway signalling, centralization, and blocking (SCB) systems are among the most critical safety components of railway transport, as they directly regulate train movement, route setting, and interval control between trains. In accordance with the Technical Operation Rules of Railways of Ukraine and Ukrzaliznytsia standards, these systems require a highly reliable and uninterrupted power supply, since any failure in their operation may lead to serious disruptions in traffic safety and train movement organization [11, 18].

The power supply of signalling and control devices is typically organized through dedicated low-voltage distribution networks that are independent from general railway consumers. This separation ensures higher operational reliability and reduces the risk of system-wide failures. To guarantee continuous operation, SCB systems are equipped with резервные (backup) power sources, including аккумуляторные батареи (storage batteries), uninterruptible power supply units, and diesel generator installations. These backup systems automatically activate in case of external power failure, ensuring that signalling devices continue functioning without interruption.

Particular attention is paid to the stability and quality of electrical parameters such as voltage level, frequency stability, and load balancing. Even minor deviations in power supply can affect the accuracy of relay-based and microprocessor-based signalling systems. Therefore, modern railway signalling infrastructure increasingly relies on stabilized power units and automated monitoring systems that continuously control power supply conditions.

An important aspect of railway electrification is electromagnetic compatibility between traction power systems and signalling circuits. Since traction currents generate strong electromagnetic fields, they may cause interference in signalling cables and control lines. To prevent such interference, special technical measures are implemented, including the use of shielded cables, optimized grounding systems, separation of power and signalling circuits, and installation of filtering devices. These measures ensure reliable transmission of control signals and prevent false activation of safety systems [18].

Another critical area is the protection of underground metallic structures located in the vicinity of electrified railway lines. These structures include pipelines, communication cables, drainage systems, and other engineering networks. They are exposed to the influence of stray currents generated by the return traction current flowing through rails and the ground. Over time, these stray currents can cause electrochemical corrosion, which significantly reduces the service life of metallic infrastructure.

To mitigate these effects, a комплекс защитных мероприятий (complex of protective measures) is applied. These include insulating coatings on pipelines, installation of drainage protection systems that redirect stray currents, and electrochemical protection methods such as cathodic protection systems. In addition, proper grounding and bonding techniques are used to equalize electrical potentials and reduce corrosion risks.

Thus, the power supply system of signalling and control devices, together with protection measures for underground structures, forms an integrated safety framework that ensures not only the reliable functioning of railway automation systems but also the long-term preservation of adjacent infrastructure in electrified railway zones.

At sections where different electric traction systems meet, such as alternating current (AC) and direct current (DC), special docking zones are arranged to ensure safe and uninterrupted operation of railway traffic. These zones are critical elements of electrified railway infrastructure, as they provide a controlled transition between systems with different voltage levels and technical characteristics [12].

Such sections are equipped with neutral inserts (neutral sections) in the contact network, where the electrical supply is temporarily disconnected. These neutral zones are designed to prevent direct electrical connection between two incompatible traction systems and eliminate the risk of short circuits or equipment damage. As a train passes through this section, it coasts without power, relying on its kinetic energy to safely complete the transition.

In addition to neutral inserts, docking zones are equipped with signalling and control devices that inform locomotive crews about the approaching system change. Clear visual and operational instructions are provided through signals, speed restrictions, and automatic monitoring systems to ensure safe passage through the transition area.

Two main operational solutions are used in these zones. The first is the use of dual-system locomotives capable of operating under both AC and DC power supply conditions without stopping. The second is locomotive exchange, where the train is stopped at a designated station and the locomotive is replaced with one compatible with the next electrification system. The choice of method depends on traffic intensity, line category, and technical infrastructure.

Special attention is given to the synchronization of operational processes in docking areas, as any delay or error may affect the stability of train schedules on both sections [17]. Therefore, these zones are equipped with advanced dispatch control systems and are closely monitored by railway energy and traffic management services.

Overall, the organization of docking points between different electric traction systems is aimed at ensuring continuous train movement, maintaining electrical safety standards, and minimizing operational delays during transitions between electrified railway sections.

Therefore, the contact network system must ensure high operational reliability, minimal maintenance requirements, and long service life while maintaining stable energy supply conditions for electrified railway transport.

Check questions

1 What are the main components of the railway power supply system on electrified railways, and what functions do they perform?

2 What is the difference between alternating current (AC) and direct current (DC) traction systems used in railway transport in Ukraine?

3 What are traction substations, and what role do they play in ensuring reliable operation of electrified railways?

4 What are the main requirements for the design and installation of the contact network, including suspension geometry and support placement?

5 How is compatibility ensured at docking sections between different electric traction systems, and what technical solutions are used for safe train passage?

Lecture 5

SIGNALING AND COMMUNICATION FACILITIES AND DEVICES. AUTOMATION AND COMMUNICATION IN RAILWAY TRANSPORT. SIGNALING DEVICES AND THEIR PURPOSE. THE IMPACT OF THESE DEVICES ON TRAFFIC CAPACITY AND SAFETY. PURPOSE AND TYPES OF COMMUNICATION IN RAILWAY TRANSPORT. SIGNALS. PURPOSE OF SIGNALS. CLASSIFICATION OF TRAFFIC LIGHTS. SIGNALS GIVEN BY TRAFFIC LIGHTS AND SEMAPHORES. PORTABLE AND MANUAL SIGNALS. TRAIN SIGNALS

An extensive network of telephone and radio communication operates on railways to ensure reliable interaction between stations, railway management, dispatching centers, and operational facilities, as well as communication between train dispatchers and locomotive crews[15].

Train movement safety and regulation are ensured through signaling, centralization, and blocking (SCB) systems, which include automatic and semi-automatic block systems (AB and PAB), dispatching centralization (DC), and automatic control devices. These systems provide interval regulation of train movement and maintain safe separation between trains on the same track[19].

Level crossings are equipped with automatic crossing protection systems, while turnouts (switches) are fitted with electrical or remote-controlled centralization systems that allow safe and efficient route setting. At marshalling (hump) yards, automatic hump control systems (HCS) are used to regulate the disbanding of freight trains[11,12].

During winter conditions, electric switch heaters are used to prevent snow and ice accumulation and ensure reliable operation of track switches[13].

For coordination of railway operations, various types of communication are used, including train dispatching communication, energy dispatching communication, interstation communication, station communication, and local operational communication. All these systems ensure continuous coordination between different railway units.

The operation and maintenance of signaling and communication systems are carried out by specialized railway signaling and communication services, which monitor technical parameters, ensure reliability of equipment, and supervise the condition of centralization, blocking systems, cables, relays, and power supply elements[15,16].

Maintenance of signaling equipment is organized through specialized repair units and technical bases. At some railway sections, mobile maintenance teams perform replacement of field equipment, while permanent production units handle scheduled maintenance and repair of non-removable systems.

Signaling, centralization, and blocking systems are installed both at stations and along railway lines.

Trackside safety systems include semi-automatic block systems (PAB), automatic block systems (AB), automatic locomotive signaling (ALS), dispatch control systems (DC), and trackside traffic light signaling[21].

Station-based control systems include electrical centralization (EC), dispatching centralization (DC), and integrated automation systems used for managing station operations.

Semi-automatic block systems regulate train movement on sections with lower traffic density, where movement authorization is given sequentially between stations.

Automatic block systems ensure continuous interval regulation of trains, where a track section is automatically closed when a train enters and reopened after it is cleared.

Automatic locomotive signaling transmits signal indications directly to the locomotive cab, informing the driver about the state of the upcoming traffic light.

It works in combination with automatic block systems and may include automatic train stop devices that enforce braking if a signal is passed at danger.

Electrical centralization (EC) is a system in which the control of switches (turnouts) and signals is carried out from a single control post, allowing centralized management of station operations and safe route setting.

Dispatching centralization is a complex system combining electrical centralization (EC) and automatic block systems (AB), which enables a train dispatcher to control and monitor the operation of multiple stations within an entire railway section from one control center, ensuring coordinated train movement and higher traffic efficiency.

Dispatch control of train traffic is used on lines equipped with automatic block systems. It provides the dispatcher with real-time information about route settings, occupied block sections, track occupancy at intermediate stations, and the indications of entrance and exit signals, improving operational control and safety.

Automatic barrier devices are used to ensure traffic safety at railway level crossings by automatically regulating road traffic when trains approach.

Signaling on railways: classification and purpose of signals

Railway signaling is designed to ensure traffic safety, organized train movement, and efficient operational control of trains and shunting operations[20].

Signals used in railway transport are classified by method of perception into visual and audible signals.

Visual signals are expressed through color, shape, position, and number of signal indications. Depending on the time of use, visual signals are divided into daytime, nighttime, and 24-hour signals.

Daytime signals are used in daylight conditions and are given using disks, boards, flags, signal posts, switch indicators, track barriers, derail devices, and hydraulic columns.

Nighttime signals are used in darkness and are displayed using colored lights on handheld lamps, locomotive lamps, signal posts, and fixed signal devices[21].

24-hour signals are used both day and night and include traffic light indications of specific colors, route indicators, permanent speed restriction signs, yellow square boards (reverse side green), red markers with reflectors indicating train tail, and other fixed signal signs. In tunnels, only nighttime or 24-hour signals are used.

Visual signals, depending on the type of devices used, are divided into permanent, portable, train, and hand signals.

Permanent signals include fixed installations such as traffic lights placed at defined locations along railway tracks. They are further divided into main and warning signals. Main signals protect stations and block sections and regulate train movement by permitting or prohibiting entry.

Portable signals include temporary devices such as boards, flags, and lamps used for temporary track protection or rolling stock fencing.

Train signals include disks, flags, and lights used to indicate the head and tail of a train.

Hand signals are given by railway personnel using flags, disks, or lamps to transmit operational commands and instructions.

Audible signals are expressed through combinations of sound lengths and patterns. They are given using locomotive whistles, railcar horns, special rolling stock horns, brass horns, and hand whistles.

Signal indicators and signal signs are used in addition to main signals to provide supplementary instructions and operational information to locomotive crews.

Signal indicators are fixed devices used on railway infrastructure to transmit specific operational information to locomotive crews regarding route conditions, track status, or technical requirements.

Route indicators indicate the direction of train movement or the track of reception. They may be presented as light signals, letter indicators, or mounted on traffic light masts.

Turnout indicators show the position or setting of a switch (turnout), indicating whether the route is set for a straight or diverging track.

Track barrier indicators show that a track section is closed for movement. They are usually displayed as light signals or arrow indicators.

Hydraulic column indicators show the presence of water supply devices and are used in specific operational areas where locomotive servicing is performed.

Pantograph lowering indicators signal the need to lower the current collector when approaching neutral sections (dead zones) without power supply.

Overheating box indicators are installed on sections equipped with automatic monitoring systems and indicate overheating or faults in rolling stock axle boxes.

Signal signs are fixed or temporary markers that require a specific action from the locomotive driver. They are classified into permanent, warning, and temporary signs.

Permanent signal signs include indicators such as "attention to current collector," "raise current collector," speed limit posts, station boundary markers, "beginning of dangerous section," "end of dangerous section," whistle signals (whistle board), and stopping markers for locomotives.

Warning signal signs include instructions such as switching off or switching on current for electric locomotives and electric trains, end of contact wire sections, stopping points for the first car, and similar operational warnings.

Temporary signal signs include instructions related to track works or special conditions, such as "prepare to lower pantograph," "lower pantograph," "raise pantograph," "raise knife switch," and "close wings," as well as other temporary operational commands.

Traffic lights are the main signaling devices in railway transport. A traffic light is an optical device that transmits visual signals both during daytime and nighttime using one or more colored lights. Depending on their design, traffic lights are divided into lens (color-light) and projector (spotlight) types.

Entrance signals: allow or prohibit a train from entering a station from the track section.

Departure signals: allow or prohibit a train from leaving a station onto a track section.

Block signals: regulate train movement between adjacent block sections and ensure interval control of trains on open line sections.

Route signals: authorize or restrict train movement within station areas, from one station track or route to another.

Protection signals: ensure safety at level crossings with roads, tram lines, trolleybus lines, and other intersecting traffic routes.

Warning signals: inform the driver about the approach to main signals and indicate their aspects in advance.

Shunting signals: regulate shunting operations within stations, including movement of wagons during sorting and formation of trains.

Hump signals: control the process of rolling wagons from a hump (sorting yard) during train disbanding.

Stop (barrier) signals: transmit an immediate stop command in dangerous situations, as well as during track closures, inspection zones, or protection of infrastructure areas.

Repeating signals: provide additional information about the aspect of main signals when direct visibility is limited.

Locomotive signals: transmit information directly to the cab of the locomotive about movement permission, signal indications ahead, and route conditions.

Types of communication in railway transport

Railway transport uses several types of communication to ensure safe and coordinated train operations, including telephone, radio, telegraph, and digital communication systems.

By functional purpose, communication is divided into operational (train and station communication), dispatching (train dispatch, energy dispatch, and traffic control), interstation communication, station communication, line communication for maintenance services, and administrative communication. These systems ensure coordination between all structural units of the railway and support safe train movement and infrastructure management [22].

Railway signaling and communication systems form an integrated complex that ensures safe and efficient train movement. Signaling devices control train intervals and movement authorization, while communication systems provide reliable coordination between dispatchers and railway units. Together with automation systems, they increase capacity, improve safety, and reduce accident risks.

Check questions

1 What is the main purpose of signaling, centralization, and blocking (SCB) systems on railways?

2 What is the difference between automatic blocking (AB) and semi-automatic blocking (PAB)?

3 What types of visible railway signals are used according to the time of their application?

4 What are the main functions of traffic lights in railway transport?

5 What types of communication are used on railways to manage train movement and railway operations?

Lecture 6

LOCOMOTIVE ECONOMY. THE MAIN FUNCTIONS AND PURPOSE OF THE LOCOMOTIVE ECONOMY. STRUCTURE AND CHARACTERISTICS OF THE MATERIAL AND TECHNICAL BASE. CLASSIFICATION OF STRUCTURES AND DEVICES AND THEIR FUNCTIONAL PURPOSE. MANAGEMENT OF OPERATIONAL WORK OF LOCOMOTIVES. MAINTENANCE OF LOCOMOTIVES BY TEAMS. CHARACTERISTICS OF THE LOCOMOTIVE REPAIR SYSTEM. INDICATORS OF LOCOMOTIVE UTILIZATION. CARRIAGE ECONOMY. GENERAL INFORMATION ABOUT THE WAGON INDUSTRY. CLASSIFICATION AND MAIN TYPES OF WAGONS. THE MAIN ELEMENTS OF WAGONS. TECHNICAL AND ECONOMIC CHARACTERISTICS AND INDICATORS OF WAGON UTILIZATION. SYSTEM OF MAINTENANCE AND REPAIR OF WAGONS. CAR DEPOTS AND TECHNOLOGY OF THEIR WORK

Locomotive management is responsible for ensuring reliable transportation work on the railways of Ukraine in accordance with planned traffic volumes, using technically serviceable locomotives that comply with the Technical Operation Rules [23]. Locomotives must be properly supplied with fuel, sand, water, lubricants, and other necessary materials, and be serviced by qualified locomotive crews [7, 16].

The locomotive economy includes a fleet of locomotives, a developed repair and maintenance base, systems of mechanized and automated equipment, and various technical facilities that support efficient operation and maintenance processes [24].

The locomotive economy provides traction for train operations and ensures the technical readiness of rolling stock. Its infrastructure includes main and turnaround (revolving) locomotive depots [23].

The main locomotive depot is a linear production unit assigned with a fixed fleet of locomotives. It performs scheduled maintenance and current repairs, equips locomotives for operation, organizes their efficient use, and ensures staffing and training of locomotive crews and related personnel [4]. Its primary function is to guarantee the planned volume of freight and passenger transportation using fully operational locomotives prepared for service. The depot also carries out repair of mechanical, testing, and auxiliary equipment, as well as maintenance of production and service facilities.

The turnaround depot is located at locomotive circulation points and serves locomotives between trips. Its functions include short-term servicing, preparation for return trips, and execution of routine maintenance operations such as TO-2 and minor current servicing.

The carriage (wagon) economy is an essential part of railway transport that ensures the availability and technical condition of wagons for freight and passenger transportation. It includes wagon fleets, maintenance bases, repair facilities, and operational management systems.

Wagons are classified according to their purpose into passenger, freight, and special types. Freight wagons include open wagons, covered wagons, tank wagons, flat wagons, and specialized wagons designed for specific types of cargo [5].

The main structural elements of wagons include the body, underframe, bogies, wheelsets, braking system, and coupling devices. Each element plays a key role in ensuring safety, load capacity, and operational reliability.

Technical and economic indicators of wagon utilization include load capacity, wagon turnover time, mileage, utilization coefficient, and maintenance costs. These indicators determine the efficiency of wagon operation in the transport process.

The system of wagon maintenance and repair includes scheduled inspections, current repairs, depot repairs, and capital repairs. This system ensures continuous technical readiness and safety of wagons during operation.

Wagon depots are specialized enterprises responsible for maintenance, repair, inspection, and preparation of wagons for operation. Their work is organized using technological processes that ensure efficient servicing, defect detection, and restoration of wagon operability.

A main locomotive depot is a complex industrial facility that ensures maintenance, repair, and operational readiness of locomotives. Its typical structure includes: locomotive repair and maintenance workshops (for scheduled servicing and current repairs); inspection and servicing positions for technical control of locomotives; locomotive stabling tracks for parking, preparation, and turnaround operations; fueling and material supply facilities (diesel fuel, sand, lubricants, spare parts storage); turning and maneuvering devices such as turning triangles or turntables for changing locomotive direction; administrative and operational buildings for management, dispatching, and personnel services; auxiliary workshops and technical rooms for equipment repair and maintenance.

According to the type of traction service, main locomotive depots are classified into passenger, freight, and mixed depots. By the nature of their activity, they are divided into operational depots, which focus on daily locomotive operation, and repair-operational depots, which combine operation with scheduled maintenance and repair functions. Some depots specialize exclusively in specific types of repairs, including PR-3 and in certain cases PR-2, serving the needs of the entire railway network.

For maintenance and repair of assigned locomotives, each main depot is equipped with a complex of technical, production, and administrative facilities. The depot territory includes a developed system of tracks for locomotive movement and stabling, as well as turning devices that allow changing the direction of locomotives. It also includes servicing points for technical inspection, repair workshops, and infrastructure for fueling and supply.

Locomotive depot buildings and facilities can be organized in different layouts. In a rectangular layout, repair workshops and servicing positions are arranged along straight or parallel tracks. These depots may have either through tracks, where locomotives can pass directly through the workshop area, or dead-end tracks, where entry and exit occur from the same side.

Depending on the arrangement of production areas, rectangular depots are divided into pavilion-type layouts, where workshops and servicing positions are located in separate parallel buildings, and stepped layouts, where facilities are arranged in a sequential or staggered configuration to optimize space and workflow.

Another common type is the fan-shaped depot, where tracks radiate from a central turning device such as a turntable or a turning triangle, allowing locomotives to be directed into different workshop or stabling tracks. Combined depot layouts may integrate elements of both rectangular and fan-shaped configurations depending on operational needs.

According to the type of traction equipment, locomotive depots are divided into diesel locomotive depots, electric locomotive depots, motor-car depots, and mixed depots. At large railway junctions, separate depots may be organized for passenger and freight locomotives to improve specialization and efficiency.

Locomotive crew change points are located mainly at regional stations and are placed under the condition of ensuring the normal duration of work of the crews.

Equipment points are located on the depot territory. Sometimes equipment devices are placed directly on the receiving-departing tracks to perform operations without uncoupling the locomotive from the train. Locomotives are equipped in the depot on specially equipped tracks in closed equipment rooms. Equipment devices and inspection trenches, where the lower part of the locomotive is inspected, and for electric locomotives, in addition, special platforms for inspection of current collectors are located in such a way that all operations can be combined in time. The process of equipping diesel locomotives includes supplying water for diesel engine cooling. This water is prepared from chemically treated condensate. The mileage of an electric locomotive and a diesel locomotive between equipments is also limited by the supply of sand on the locomotives [4].

Distribution of the locomotive park.

All locomotives assigned to the depot and kept on their balance sheet make up the so-called inventory park, which is divided into operated and non-operated. The operated fleet consists of locomotives that are in operation, in the process of equipping, technical maintenance TO-2, acceptance and delivery, as well as waiting for work.

The decommissioned fleet consists of locomotives that are in all types of current repairs, in reserve, in the process of forwarding and technical maintenance TO-3.

Types of locomotives operated by Ukrzaliznytsia. According to the type of work, locomotives are divided into freight, passenger and shunting locomotives [25].

Locomotives of the following series are used for freight traffic:

direct current electric locomotives – VL-8, VL-10, VL-11, VL-23;

mixed current – VL-82, VL-82m;

alternating current VL-60, VL-80;

diesel locomotives – 2TE10UT, 2TE116[4].

For passenger traffic:

direct current electric locomotives – ChS-2, ChS-7;

alternating current electric locomotives – ChS-4, ChS-4t, ChS-8;

locomotives - M62, TEP70, TEP60 [4].

Diesel locomotives of the ChME series, as well as TEM and TGM are mainly used for shunting work.

Trains with locomotive traction or diesel trains - DR-1, DR-2, D-1 are used for suburban traffic. Electric trains EP-2, EP-2P, EP-200, EPL-2T, EP-2T operate on electrified direct current lines, EP-7, EP-9П, EP-9E, EP-9T on alternating current [4].

Locomotives assigned to the main depot service trains according to the traffic schedule within the sections where the main and revolving depots are located.

Ways of servicing trains with locomotives.

Locomotive servicing systems are based on the organization of locomotive circulation between the main depot and points of turnaround along defined operating sections. The operating area of locomotives between the main depot and circulation stations is called a traction shoulder.

In the shoulder servicing system, locomotives assigned to the main depot operate within a fixed section between the departure station of the depot and the turnaround points. After delivering a train to the destination station, the locomotive is uncoupled, returns separately or with a return service train back to the main depot, and undergoes servicing procedures such as refueling, technical inspection, maintenance, and crew change. After preparation, the locomotive is again assigned to the next train. This method is characterized by repeated return of locomotives to the depot and is typical for simpler operating schemes with clearly defined service limits [15].

To reduce locomotive downtime at main depot stations and improve operational efficiency, a circular (ring) servicing system is used. In this system, locomotives continuously circulate along the route without returning to the depot after each trip. Trains pass through the main depot station without uncoupling the locomotive, while locomotive crew changes are carried out directly on station tracks. Technical servicing and refueling are performed at designated circulation points. Locomotives enter the main depot only when scheduled maintenance or repair is required, which significantly reduces idle time and increases utilization efficiency.

The loop servicing system is a variation of the circular method and is applied when a main depot is connected to at least two traction directions. In this case, locomotive movement forms a closed operational loop between several routes, allowing more flexible redistribution of locomotive flows and improving overall efficiency of train operations [4,13].

Ways of servicing locomotives by crews

World railway practice shows that the most effective locomotive crew organization methods include shift (variable), attached, and tour systems.

The shift method of servicing locomotives is mainly used on long-distance sections. In this system, locomotives are not permanently assigned to a specific crew. Instead, they are operated by alternating shift crews that take over duties according to a schedule. Crew changes can take place either at main depot stations or at locomotive turnaround points. This method increases average daily locomotive mileage and circulation efficiency, while reducing the total required fleet size.

The attached method is widely used on the railways of Ukraine for both shunting and mainline locomotives. In this system, a locomotive is permanently assigned to a fixed number of crews (usually two to four). These crews operate the locomotive in rotation after completing their rest periods at their place of residence, where crew change takes place. This approach improves the quality of locomotive maintenance during operation, as crews are consistently responsible for the same locomotive and are more familiar with its technical condition.

The tour method is applied in cases where one crew operates the locomotive while another rests in a special rest or trailer car. This system allows continuous operation over long distances while ensuring regulated rest conditions for personnel.

To maintain locomotives in proper technical condition and prevent failures during operation, Ukrzaliznytsia applies a scheduled preventive maintenance system combined with ongoing repairs. Locomotives are sent for maintenance based on standardized mileage or operating time. The system is based on fixed repair scopes, preventive technical inspections before failures occur, and a cyclic structure of maintenance with alternating levels of complexity depending on the condition of the locomotive.

The wagon economy is an important branch of railway transport responsible for ensuring safe and efficient passenger and freight transportation. Its main tasks include maintaining wagons in technically sound condition, preparing them for operation, and guaranteeing the safety of both passengers and transported cargo.

The wagon economy includes wagon repair plants, wagon depots, wagon preparation points, technical maintenance points, commercial inspection and control facilities, mechanized repair points, specialized tracks for major repairs, brake testing stations, inspection and control posts at stations, automated hot-box detection systems, railway workshops, container depots, trolley exchange points for international traffic, and facilities for servicing refrigerated rolling stock.

Classification and main types of wagons.

Railway rolling stock is divided into passenger and freight wagons.

Passenger wagons include passenger cars for transporting people, postal wagons, baggage wagons, dining cars, and special-purpose wagons such as service, laboratory, or staff wagons.

Depending on comfort level and operating range, passenger wagons are classified into long-distance, interregional, and suburban types. Long-distance wagons may include luxury, soft, compartment, reserved seat, and general types.

Passenger wagons are equipped with heating, ventilation, and lighting systems. Electrical energy is generated by axle-driven generators or supplied from a power car included in the train composition. When trains are stationary at stations, onboard batteries provide power, which are recharged during movement.

Covered universal wagons are designed to transport various cargoes that require protection from the effects of atmospheric or other external factors.

Gondola wagons are the most numerous type of freight fleet and are designed mainly for the transportation of bulk or bulk cargoes of open storage.

Universal platforms are designed for the transportation of long, heavy and bulky cargoes.

Tanks are also a fairly popular type of freight wagons. They transport both bulk cargoes (mainly petroleum products) and a wide range of loose dusty cargoes of covered storage (cement, mineral fertilizers, chemical raw materials, etc.).

Isothermal wagons transport perishable cargoes. Isothermal wagons are combined into trains or sections of five or more units and are equipped with diesel generator sets and refrigeration equipment.

For the transportation of heavy and oversized cargo, which is very profitable, transporters with a carrying capacity of 130 tons (twelve-axle) to 500 tons (thirty-two-axle) are used.

Main elements of wagons.

The main elements of wagons include: the running gear, which carries the load from the frame and ensures smooth movement of the wagon; the wagon frame, which perceives the load from the body and serves as the base for mounting all wagon equipment; the body, which accommodates passengers or cargo; shock-traction devices, which serve to couple the wagons together and with the locomotive, as well as to mitigate longitudinal loads and shocks during coupling and during sorting operations; braking equipment, which ensures a reduction in speed or stopping the train.

The load capacity of a wagon is the largest mass of cargo that can be transported on it under the conditions of the strength of the wagon structure.

The wagon's container, that is, the mass of its own structure, together with the mass of the cargo, makes up the gross mass of the wagon.

Wagon maintenance and repair system.

For freight wagons: wagon management units perform Technical Inspection at sorting and section stations when preparing trains for a trip, as well as when presenting them for inspection before loading; PR-1 – current repair; for empty wagons during comprehensive preparation for transportation on specialized tracks; PR-2 – with uncoupling wagons from transit and arriving trains or formed trains; depot – to restore the operability of wagons with the replacement or repair of individual components and parts.

Current repairs are carried out by uncoupling from the train or train at the points of formation or circulation and sending them to specialized repair tracks or to the wagon depot.

Depot repairs are planned, they are carried out to restore operability with the replacement or repair of individual components [26].

Car depots and their operation technology.

Car depots are specialized linear production enterprises of the car industry. By specialization, depots are divided into passenger, freight, refrigerated, and special for container repair. There are also mixed-type depots [26].

Wagon depots are intended for depot and current uncoupling repairs of wagons, as well as the manufacture, repair and assembly of components and spare parts for a number of PTOs attached to this depot. On the basis of the wagon depot, the preparation of wagons for transportation, as well as the maintenance of freight and passenger wagons within the relevant sections, is organized and ensured.

The wagon depot has the following production units:

workshops: assembly, wheel-bogie, mechanical, automatic (auto couplers and auto brakes), axle box, painting, forging and spring, woodworking, electric welding;

sections: electrical department (in passenger and refrigerated depots), diesel-refrigeration (in refrigerated depots);

departments: tool, warehouse, regeneration, repair of hatch covers and doors of gondolas, etc.

In order to improve traffic safety and timely detect the presence of faulty axle units in a train at stations with non-stop freight trains, as well as at crossings at the approaches to hub stations, railway tracks are equipped with hot axle unit detection points (PONAB) [4].

If the train arrived at the disbanding, then after the disbanding of the train, the wagons are accumulated in the marshalling yard, where they are also serviced, and those malfunctions that were not fixed in the arrival yard, as well as new ones that appeared after the disbanding of the train, are eliminated.

In the departure yard, the trains undergo inspection and maintenance, troubleshooting, and a test of the auto brakes. The driver is issued a certificate of the operation of the auto brakes when the train is ready to depart. The total duration of the train processing in the departure yard should not exceed 30 minutes.

The modern technological process of the work of technical (sorting and district) stations should ensure four basic principles: continuity, rhythm, parallelism and flow of all operations and their maximum combination with high quality of execution.

The following main operations are performed with transit trains: technical and commercial inspection; elimination of technical and commercial malfunctions of the wagons; testing of the auto brakes; change of the locomotive or only the locomotive crew.

Check questions

1 What is the main task of the Main Locomotive Depot (MC)?

2 What are the three main methods of servicing locomotives by crews?

3 Which locomotives are mainly used for freight transportation in Ukraine?

4 What are the main types of freight wagons used on railways?

5 What are the main elements of a railway wagon?

Lecture 7

SEPARATING POINTS. STATIONS AND THEIR CLASSIFICATION. BASIC INFORMATION AND TECHNOLOGY OF STATIONS. ARRANGEMENT OF STATIONS. OPERATIONS AT STATIONS. TECHNOLOGY OF TRAIN HANDLING AND DISBANDING AND FORMING TRAINS. MANAGEMENT OF STATION OPERATIONS. MAIN INDICATORS OF STATION OPERATION.

To ensure the passage of the required number of trains along a railway section and guarantee traffic safety, railway lines are divided into sections or block sections by dividing points (DP).

Dividing points equipped with track development include junctions, overtaking points, and stations.

Dividing points without track development include track posts used in semi-automatic blocking systems, passing traffic lights in automatic blocking systems, and, in the absence of both, block section boundaries defined by automatic locomotive signaling.

A junction is a dividing point on single-track lines equipped with track development intended for crossing and overtaking trains.

An overtaking point is a dividing point on double-track lines equipped with track development that allows trains to overtake one another and, if necessary, transfer a train from the main track to another.

A station is a dividing point with track development that enables train reception, departure, crossing, and overtaking, as well as freight, baggage, and passenger operations. When sufficiently developed, stations also perform shunting operations related to train formation, disbanding, and technical servicing [27].

According to their operational function, stations are classified into district, intermediate, marshalling (sorting), passenger, passenger-technical, and freight stations. Freight stations are further divided into non-specialized, specialized, transshipment, port, and ferry stations.

A district station is intended for handling transit freight and passenger trains, performing shunting operations for the formation and disbanding of group and district trains, as well as servicing industrial access tracks.

Intermediate stations are designed to perform technical operations such as reception, departure, overtaking, crossing, and passing of freight and passenger trains, as well as passenger boarding and alighting, loading and unloading of cargo and luggage, and shunting operations related to coupling and uncoupling wagons in group trains. This is the most common type of station. Intermediate stations are located on all railway lines and are typically situated between district stations at intervals of approximately 15–20 km.

Marshalling (sorting) stations are intended for the large-scale processing of wagons and the formation and disbanding of trains of all categories, including through, district, group, export, and transfer trains. They are located at major points of freight formation or termination, at junctions where railway lines merge or intersect, and within large railway hubs. In addition, they handle transit trains, perform locomotive and crew changes, carry out maintenance and technical inspection of wagons, and perform shunting operations. Passenger and freight operations are also performed, but on a limited scale [28].

Passenger stations are designed to perform passenger service operations and to organize passenger train traffic, including handling of tickets, baggage, and mail.

Passenger technical stations are intended for the preparation of passenger trains for operation. This includes technical inspection, maintenance, repair, and servicing of passenger and dining cars, formation and disbanding of passenger trains from assigned rolling stock, delivery and removal of trains to passenger stations, and storage of trains awaiting departure.

Freight stations are designed to perform freight and commercial operations involving cargo and freight wagons, including storage, loading, unloading, sorting, weighing of goods, and formation of shipping routes. They are typically located in large industrial and administrative centers, as well as in areas of seaports and river ports.

Non-specialized freight stations, including linear freight or supporting intermediate stations, are intended for handling mainly packaged and piece goods transported in containers, as well as certain types of bulk cargo. They also serve industrial enterprises, warehouses, and logistics bases not classified as public-use freight terminals.

Specialized freight stations are designed for the mass loading and unloading of homogeneous cargo such as grain, coal, ore, mineral and construction materials, oil products, timber, and similar bulk commodities.

Transshipment stations perform large-scale cargo transfer between railway lines of different gauges (narrow gauge to standard gauge and vice versa), as well as between different transport systems where applicable.

Port stations are intended to serve seaports and river ports and provide for the transfer of cargo between rail and water transport. They are located in close proximity to port facilities or directly within port territories.

Ferry stations are designed to serve railway ferry crossings and ensure the transfer of rolling stock across water barriers.

Stations are also classified according to their functional characteristics.

An international transfer station is equipped with the necessary track layout, technical facilities, and personnel to ensure the transfer of rolling stock between countries in accordance with technical and commercial requirements, including the execution of border control procedures. Such stations process transfer documentation and transmit the necessary data to railway information systems for accounting and monitoring of rolling stock movement [29].

A nodal station is an intermediate, district, or marshalling station to which at least three railway lines converge. If multiple lines connected to one station run together toward another junction or marshalling station on common or parallel tracks, such a station is referred to as a pre-nodal station.

A junction station is a dividing point where railway directions powered by different types of current are connected. In the overhead contact system of such stations, switching devices allow the supply of different traction current systems.

Depending on workload and technical complexity, stations are divided into classes. Stations with the highest volume of operations and the most advanced technical equipment are classified as out-of-class stations, followed by stations of classes I through V [7].

Railway tracks at dividing points are classified into station tracks and special-purpose tracks.

Station tracks include all tracks within station limits, such as main tracks, reception and departure tracks, sorting tracks, arrival and departure yards, loading and unloading tracks, depot tracks (for locomotive and wagon facilities), and connecting tracks.

The length of a reception and departure track must be not less than the length of the design train, ensuring that the entire train can be accommodated during operational procedures [10].

The extension tracks are located on straight track sections, and in difficult terrain conditions they may be placed on curves with a radius of at least 1200 m[10]. It is not permitted to design extension tracks on reverse curves directed in opposite directions due to safety and operational constraints.

Special-purpose tracks include safety tracks, catch sidings (intercepting dead ends), and industrial access tracks serving enterprises.

Main tracks, in accordance with the Rules for Technical Operation, include the tracks of main lines as well as station tracks that are a direct continuation of adjacent line tracks and, as a rule, have no turnout deviations at switch points.

Tracks intended for the same operational purpose are combined into track groups called yards or parks. Depending on their function, the following types of track parks are distinguished: reception and departure parks for handling incoming and outgoing trains, classification (sorting) parks for wagon processing and train formation, loading and unloading parks for cargo operations, locomotive parks for repair and maintenance of locomotives, servicing parks for supplying locomotives with fuel, water, and other materials, repair parks for freight wagon maintenance, technical parks for servicing passenger trains including cleaning, disinfection, washing, and reconfiguration of cars, shunting parks for the formation and adjustment of passenger trains, local parks at stations with intensive wagon flow requiring grouping by destinations or unloading points, and transit parks for receiving and dispatching trains without processing [30].

The area where turnouts connecting tracks and parks are arranged is called the throat (switch neck) of the station. Its design must ensure required line capacity and safe train movement.

A distinction is made between full length and useful length of a track. The full length of a through track is the distance between the extremities of the turnouts leading to that track, while for a dead-end track it is measured from the turnout to the buffer stop.

The usable length of a track is the part of its total length within which rolling stock may be placed without violating the safety of movement on adjacent tracks. It is limited by boundary posts, exit or shunting signals, turnouts, and supporting structures. Boundary posts are installed at locations where the distance between the axes of converging tracks reaches 4.1 m.

The usable length of reception and departure tracks for freight traffic is determined based on the planned train length for the tenth year of operation, taking into account standardization of train lengths in interconnected directions. Typical standardized values include 1550 m, 1250 m, 1050 m, and 850 m, depending on line category and operational requirements [10].

Station tracks are numbered according to established railway rules. Main tracks are assigned Roman numerals, with even-direction tracks designated as II, IV, and odd-direction tracks as I, III [12]. All other station tracks are numbered using Arabic numerals: from the side of arrival of odd-numbered trains they are assigned odd numbers, and from the side of arrival of even-numbered trains they are assigned even numbers, with numbering oriented toward the station axis.

Usable track length and correct station track numbering are crucial for safe, continuous station operations. They determine how efficiently trains can be received, dispatched, and passed, as well as how shunting is organized in the station throat. Proper use of track length increases station capacity and improves safety by avoiding route conflicts and separating train movements [31].

Check questions

1 What is the main purpose of sorting stations on the railway?

2 What operations are performed at intermediate stations?

3 What is the difference between passenger stations and freight stations?

4 What are the main types of station parks and what are they used for?

5 What is a station throat and why is it important?

Lecture 8

TRAIN SCHEDULE. INITIAL DATA AND DEVELOPMENT PROCEDURE. ELEMENTS OF THE SCHEDULE. CLASSIFICATION OF TRAIN SCHEDULES. DETERMINATION OF TRAIN SCHEDULE INDICATORS. CAPACITY AND CARRYING CAPACITY. ORGANIZATION OF OPERATIONAL WORK. TASKS TO IMPROVE THE QUALITY OF OPERATIONAL WORK. BASIC PRINCIPLES OF TRANSPORTATION ORGANIZATION. BASIC REGULATORY DOCUMENTS AND THEIR PURPOSE. THE MAIN INDICATORS OF OPERATIONAL WORK. GENERAL CHARACTERISTICS OF TECHNICAL STANDARDS OF OPERATIONAL WORK. STRUCTURE OF OPERATIONAL MANAGEMENT OF OPERATIONAL WORK. CONTENT AND STRUCTURE OF THE OPERATIONAL PLAN.

Train schedule is the organizational and technological basis for the operation of all railway units and serves as the general plan for operational work on railway transport. Strict adherence to the train schedule is ensured through the coordinated functioning of stations, locomotive depots, traction substations, maintenance points, and other infrastructure units involved in train movement, as well as through the precise execution of established technological processes [21].

The train schedule must ensure the satisfaction of passenger and freight transportation needs, guarantee the safety of train movement, and provide efficient utilization of the line's line capacity and station processing capacity [32]. It also ensures rational use of rolling stock, compliance with regulated working time limits for locomotive crews, and the possibility of performing maintenance and repair works on track infrastructure, signalling and interlocking (SCB) systems, communication networks, and power supply facilities without disrupting traffic organization [21].

A train schedule is a graphical representation of train movement in a Cartesian coordinate system, where the horizontal axis (X-axis) represents time and the vertical axis (Y-axis) represents distance [33]. The movement of a train between dividing points is expressed as a linear function of the form $Y = kX + b$, where the train is considered as a material point for simplification of calculations and analysis [7,21].

The time of arrival or departure of a train at each dividing point is determined by the intersection of the train movement line with the axis of the corresponding station or block point [21]. This time is indicated on the diagram near the intersection point for clear identification of operational parameters. At stations located within dispatching sections, train numbers are placed in accordance with established graphical notation rules: odd-numbered trains are shown with movement lines drawn from top to bottom, while even-numbered trains are shown from bottom to top. Train numbering also depends on the direction of movement and the category of traffic, ensuring clear differentiation of flows within the schedule structure.

Initial data for developing a train schedule include train running times along line sections, standard values for acceleration and deceleration, regulated dwell times at intermediate stations for technical and commercial operations, norms for locomotive turnaround at depots for maintenance and servicing, as well as calculated minimum headways between trains during reception, departure, and passage through stations (station intervals), and intervals between trains operating in packs or following one another (train separation intervals) [33].

In railway operational practice, several types of train schedules are distinguished, including the standard (normative) schedule, variant schedules, and the executed (actual) train movement schedule [21].

The normative train schedule is developed annually by specialists of the train scheduling department within the railway transport service. It is introduced on the last Sunday of May before the beginning of the summer passenger traffic period [34]. On lines where passenger traffic significantly differs between summer and winter seasons, an adjusted winter version of the schedule is implemented after the end of the summer period. Official timetable books are compiled and published based on the approved normative train schedule [21].

Variant train schedules are developed for railway sections where maintenance “windows” are scheduled, affecting train running conditions and reducing train traffic capacity. Such schedules may be introduced for long periods or for specific dates when maintenance works are performed. VGDP must ensure the planned average daily volume of train traffic on the section; otherwise, in coordination with the transportation department, alternative routing (diversion of train flows) is organized for the duration of the maintenance windows. For sections receiving diverted traffic, separate variant schedules are also developed.

The executed train movement schedule is maintained by the section train dispatcher either on a standardized form or automatically using specialized software systems. The GVR reflects the actual execution of both normative and variant schedules across all railway services. Based on its analysis, key qualitative and quantitative performance indicators of the section are determined.

Train schedules are classified according to several criteria [4,21]. By train speed characteristics on a section, they are divided into parallel schedules, where trains of the same direction move at equal speeds, and non-parallel schedules, where trains of the same direction have different speeds depending on their category. By track layout, schedules are divided into single-track, double-track, and mixed sections. By traffic direction structure, schedules may be even, odd, or balanced depending on the number of trains in each direction. By sequence of train following, schedules are classified as batch, bundle, or partially batch; batch operation is applied when only one train may occupy a section at a time.

Station intervals represent time intervals between arrival, departure, and passage of trains through a dividing point. The crossing interval is defined as the minimum time between the arrival of one train from a single-track section to a station and the departure of an oncoming train in the opposite direction on the same section.

The non-simultaneous arrival interval is the minimum time interval between the arrival of two trains moving in opposite directions at a dividing point. This interval must be observed regardless of whether one train passes through the station without stopping or both trains stop at the station.

The passing interval for trains in the same direction is the minimum time interval between the arrival of one train at a dividing point and the departure of the following train in the same direction from the previous station. This interval includes the time required for processing the arriving train, communication between adjacent stations, and the preparation and clearance of the departure signal or authorization for the second train to depart [19].

The non-simultaneous departure and arrival interval (top) refers to cases when trains moving in the same direction cannot be received and dispatched simultaneously. According to the Rules for Technical Operation, this restriction is applied when simultaneous operations are not permitted due to track profile conditions, signalling and interlocking system limitations, or when reception and departure routes are not fully separated [7].

The procedure for developing a train schedule requires, in addition to the basic elements, information on train weight norms, length standards, train categories, and other operational parameters [33]. The construction of the schedule begins with passenger train paths, followed by accelerated freight trains, priority and regular freight services, and finally all remaining train categories [21].

Local trains, including collection services, are placed on the schedule according to a pre-designed scheme aimed at minimizing wagon dwell time at intermediate stations and ensuring efficient distribution of local traffic.

Freight train paths are distributed as evenly as possible throughout the day to ensure rhythmic station operation, reduce locomotive idle time at turnaround points, and improve the utilization of traction resources, particularly on electrified lines where balanced loading of traction substations is required. For operational efficiency, freight and passenger train paths are alternated where possible, including coordination of ascending and descending traffic flows during periods of high line occupancy.

Laying freight train routes on single-track schedules usually begins with the most restrictive section of the line. A restrictive section is the section whose occupation time by a train pair or an individual train is the greatest. In most cases, it corresponds to the longest section with a difficult profile, steep gradients, or limited passing possibilities.

After the restrictive section is filled, freight train paths are distributed across the remaining sections of the schedule. On double-track lines, train paths are first laid starting from sections adjacent to major hubs or locomotive turnaround stations in order to ensure coordination of locomotive circulation and reduce idle time at these points.

The train schedule is developed for the maximum forecasted traffic volumes during its validity period. In cases of significant seasonal or operational fluctuations in traffic, as well as during planned reconstruction, capital repairs of track infrastructure, contact network maintenance, or electrification works, variant schedules are introduced for specific periods.

Planned large-scale maintenance works are included in so-called "windows," during which certain track sections are temporarily allocated to infrastructure or construction organizations for uninterrupted execution of works.

The train schedule is prepared for the entire railway network, usually for a one-year period, and is introduced in May. If necessary, it is adjusted for the winter period due to seasonal changes in transportation demand. The format of the schedule is unified for all railway administrations.

Based on the approved schedule, official passenger and freight timetables are issued for operational and public use. The development of schedules is significantly facilitated by the use of computer-based planning systems, which also allow simultaneous preparation of locomotive circulation schedules [35].

The train schedule is evaluated using quantitative and qualitative indicators. Quantitative indicators include the number of freight and passenger trains, as well as the volume of loading and unloading operations that can be handled under the given schedule [22].

The main qualitative indicators include technical speed, section speed, route speed (calculated separately for freight and passenger trains), the speed utilization coefficient, average daily locomotive mileage, average dwell time of trains and locomotives at section stations, and average train weight.

Technical speed is defined as the average speed of train movement along a section, expressed in km/h, taking into account acceleration and deceleration periods.

The section speed coefficient is the ratio of section speed to technical speed and characterizes the efficiency of locomotive utilization on line sections. The closer this coefficient is to one, the more efficiently the rolling stock is used.

Section speed is the average speed of a train between two locomotive change points, taking into account all intermediate station stops, expressed in km/h. Unlike technical speed, it includes station dwell times.

Route speed is the average daily speed of train movement from origin to destination, taking into account all stops at intermediate and dividing points. It is calculated separately for long-distance passenger trains, accelerated freight trains, and through routes, and in some cases for transit trains.

System of organization of operational work. Main indicators of railway operation.

Operational work in railway transport is the coordinated use of technical means such as rolling stock, track infrastructure, signalling and communication systems, and other facilities to ensure the continuous and safe transportation process. It is organized on the basis of the Train Formation Plan, which defines the optimal routing and grouping of freight flows and is developed annually by the Main Information and Computing Center of Ukrzaliznytsia.

The organization of freight flows is based on the most efficient technological scheme, ensuring rational use of rolling stock, minimization of empty runs, and stable operation of stations and lines. Operational work is regulated by a unified system of normative documents, including the Railway Charter, the Rules of Technical Operation, the Instructions for Train Movement and Shunting, and the Instructions for Signalling, which establish mandatory requirements for safety, train movement order, and interaction between railway units.

The main quantitative indicators of railway operation include cargo dispatch in tonnes, average daily loading and unloading in wagons and tonnes, total cargo turnover, passenger dispatch and passenger turnover, as well as wagon transfers between railway divisions and overall network workload. Financial indicators such as revenues and transportation costs are also used for performance evaluation.

Qualitative indicators characterize the efficiency of using technical resources. These include static and dynamic wagon load, average train weight, technical and sectional speeds, wagon turnover and its components, average daily mileage and productivity of wagons and locomotives, as well as labor productivity. Additional efficiency is assessed through cost indicators per ton-kilometre, passenger-kilometre, and per wagon operated.

Together, these indicators provide a comprehensive assessment of operational efficiency, reflecting both the volume of work performed and the quality of resource utilization in railway transport.

Determination of technical standards for operation and use of wagons.

Technical standards for operational wagon work are established in three main groups for interstate freight traffic. The first group includes average daily quantitative indicators that characterize the volume of work performed with the wagon fleet, such as loading and unloading volumes, acceptance and delivery of wagons at junction stations, wagon dispatch from nodes, wagon turnover, and overall freight turnover.

The second group consists of qualitative indicators that reflect the efficiency of railway operations. These include wagon turnover of the general fleet and its individual categories (empty and loaded wagons), local and transit turnover and its elements, average daily mileage of wagons and locomotives, wagon productivity, average train weight and composition, as well as other performance parameters of rolling stock usage.

The third group includes norms for providing transport resources, such as the required operational fleet of wagons by type and structure, reserve wagons, the operational locomotive fleet, and established limits for fuel and electricity consumption for train traction.

Operational standards are used as a basis for planning, monitoring, and evaluating wagon fleet utilization in both national and interstate freight traffic. They ensure coordination between stations, depots, and dispatching centers and allow balancing wagon supply with transportation demand across the railway network.

Operational traffic control includes planning, management, and regulation of train movement and local operations at stations. The operational work plan of a railway region covers key areas such as train acceptance and dispatch at junction stations, work of technical and freight stations, and organization of wagon and locomotive fleets.

The system of operational management is organized on several levels, including the central dispatching control, regional railway directorates, and station-level operational staff [33]. Each level is responsible for planning execution, real-time regulation of train flows, and ensuring compliance with technical and safety standards defined by Ukrzaliznytsia regulations.

Freight trains are classified according to route length and operational purpose into route, through, district, group, export, and transfer trains. Accelerated trains include fast freight trains, refrigerated trains, livestock transport trains, and trains carrying perishable goods.

Through trains run without processing at least one technical station, while district trains pass from one technical station to another without processing. Group trains are formed for delivering wagons to intermediate stations, whereas transfer trains operate between junction stations for wagon redistribution.

Transit service refers to the movement of wagons between railway junctions without performing freight operations, while local service involves wagon movement within one railway for the execution of loading and unloading operations.

Check questions

1 What is a restrictive section in a train schedule, and why is it important?

2 Why are freight trains distributed evenly throughout the day in the train schedule?

3 What is the difference between technical speed, section speed, and route speed of a train?

4 What are the main quantitative and qualitative indicators of railway operational work?

5 How are freight trains classified according to the distance of the route and the nature of their work?

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Lecture Notes

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