

THE MODERNIZATION IMPORTANCE OF THE TRANSPORT LABORATORY IN THE DEPARTMENT OF RAILWAY TRANSPORT

Abstract. At present, emphasis is placed on the implementation of modern technologies in education. Particular attention is given to the practical training of students, the use of modern technologies for railway traffic management, information systems used in railway operations, and the application of simulation systems in railway transport. The article also highlights the importance of the laboratory in addressing research projects and implementing modern trends such as transport digitalization, automation, and intelligent transport systems. The transport laboratory represents an important tool for linking theoretical knowledge with practical experience and contributes to the preparation of professionals capable of responding to the demands of modern railway transport.

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Introduction

Railway transport represents one of the most important pillars of the modern transport system. In a period of increasing demands for environmentally friendly, safe, and efficient transport, the importance of railway transport continues to grow. The development of new technologies, the digitalization of processes, and the implementation of intelligent transport systems create a need for high-quality technical education and research. University departments play an important role in this process by preparing future professionals for the railway sector. One such workplace is the Transport Laboratory of the Department of Railway Transport, which serves as a space for practical teaching, scientific research activities, and applied research.

The Transport Laboratory represents a modern facility equipped with technological equipment and simulation systems that enable students and professionals to analyse and model processes in railway transport. Through the laboratory, theoretical education relates to practical experience, thereby improving the quality of education and enhancing graduates' preparedness for the demands of professional practice. At the same time, the laboratory provides a space for the implementation of professional projects, experiments, and research activities in the fields of transport organization, railway operations management, and the optimization of transport processes.

growing need for the practical training of students in the field of railway transport organization and management. The development of railway infrastructure, the modernization of signalling systems, and increasing demands for transport safety created the need for specialized facilities that would enable the connection of theoretical education with practical training.

The original transport laboratory at Veľký Diel area was officially put into operation on 1 April 1994. Its establishment represented an important milestone in railway transport education, as it enabled students to gain practical experience in a simulated railway operating environment. At the time of its establishment, the laboratory was equipped mainly with model devices, basic control elements, and technical tools intended for teaching technological processes in railway transport. Despite the technical limitations of that period, it provided students with a unique opportunity to become familiar with the principles of traffic management and railway operations organization.

Since the original transport laboratory operated on the PC 284 platform, it was not possible to continuously modernize and upgrade the technological equipment that could gradually be implemented into the educational process of direct railway traffic management (Gašparík et al., 2014).

1. A brief history of the railway transport laboratory

The Transport Laboratory of the Department of Railway Transport was established in response to the

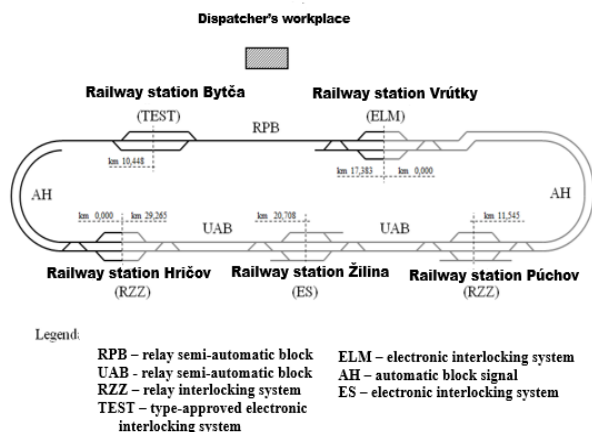


Fig 1. The Railway Circuit in the Transport Laboratory from 1994 to 2020 (Gašparík et al., 2014)

A significant milestone in the history of the department was the comprehensive modernization of the transport laboratory, which was officially inaugurated on 4 April 2024. The modernized laboratory introduced new opportunities in the field of railway transport simulation, digital traffic management, and the analysis of transport processes. The modernization included the implementation of advanced software tools, modern analytical systems, and interactive technologies used in practical teaching.

The new technological equipment enables the realistic simulation of operational situations, railway timetable planning, the modelling of extraordinary events, and the analysis of railway infrastructure capacity. At the same time, the modernized laboratory provides suitable conditions for the implementation of scientific research projects and cooperation with professional practice.



Fig 2. Technologies for Cooperation with Signalling Systems Used until 2020 (Gašparík et al., 2014)

The development of the transport laboratory reflects the overall technological progress in the field of railway transport. From simple model-based equipment, the facility has gradually evolved into a modern centre for simulation, research, and practical teaching. At present, it represents an important part of the educational process at

the Department of Railway Transport and plays a significant role in preparing future professionals for the railway sector (Gašparík et Šulko, 2016).

1.1 Characteristics of the Transport Laboratory

The Transport Laboratory of the Department of Railway Transport is a specialized facility focused on the simulation and analysis of railway transport processes. Its main objective is to create realistic conditions that enable students to understand the principles of railway operations and apply theoretical knowledge to practical situations. The laboratory provides opportunities for modelling transport situations, railway timetable planning, traffic management simulation, and the evaluation of railway infrastructure capacity.

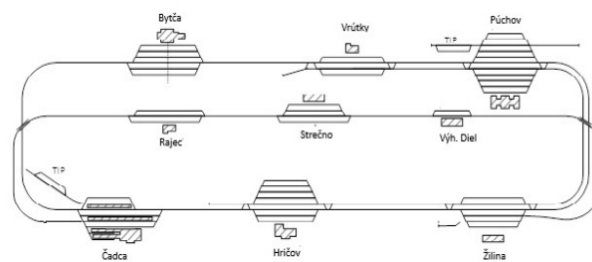


Fig 3. The Railway Circuit in the Transport Laboratory since 2024 (Gašparík et al., 2026)

An important part of the laboratory consists of modern software tools designed for the simulation of transport processes. These systems make it possible to create models of railway lines, stations, and transport hubs, while allowing users to analyse system behaviour under various operational conditions. Simulations help identify critical points in transport, propose more efficient solutions, and optimize transport organization.

The laboratory is also equipped with technical devices for monitoring and processing transport data. Its equipment may include model signalling systems, traffic control panels, computer workstations, and systems for transport data processing. As a result, students have the opportunity to become familiar with technologies used in real railway operations (Gašparík et al., 2026), (KZD, 2026).

2. Application areas of the transport laboratory

The Transport Laboratory of the Department of Railway Transport has a wide range of applications in various areas of education, research, and the practical implementation of transport technologies. One of the main areas of use is the simulation of railway operations, which makes it possible to analyse traffic flow on railway lines and at transport hubs. Simulation tools help model the behaviour of the transport system under various operational conditions and provide opportunities to examine the impact of delays, track closures, or extraordinary events on traffic flow.

Another important area is the development and optimization of railway timetables. Through laboratory applications, students and researchers can propose train schedules, analyse conflicting situations, and evaluate the efficiency of the transport system. Timetable optimization is particularly important in terms of ensuring service regularity, the efficient use of railway line capacity, and the minimization of operating costs.

The laboratory is also used in the study of railway transport safety. Simulations make it possible to analyse risk situations, identify possible causes of operational problems, and propose measures to improve transport safety. Laboratory activities may also include the modelling of signalling systems and traffic control systems.

The laboratory also plays an important role in the teaching of logistics processes and transport organization. Students become familiar with the principles of transport performance planning, vehicle circulation scheduling, and the coordination of different modes of transport. In this way, they gain a comprehensive understanding of the functioning of the transport system and its interconnections (KZD, 2026).

2.1 The importance of the transport laboratory in education

One of the most important roles of the transport laboratory is to support the educational process. Theoretical knowledge gained during lectures is complemented in the laboratory by practical exercises that enable students to better understand issues related to railway transport. Practical teaching plays a particularly important role in courses focused on transport organization, technological processes, signalling systems, and operational management.

In the laboratory, students develop the ability to analyse transport situations, design operational procedures, and solve problems arising in railway operations. A significant benefit is the possibility to simulate extraordinary events, train delays, or track closure activities, while students propose solutions to minimize the negative impacts on transport operations.

Practical training in the laboratory also fosters teamwork and communication skills. Many tasks require coordination among multiple participants, similar to real railway operations. Students thus gain experience in decision-making under time pressure and in cooperation when solving operational problems.

An important aspect of the laboratory is also the use of modern information technologies. The digitalization of railway transport requires specialists capable of working with analytical tools, databases, and simulation software. The laboratory therefore prepares students for the conditions of modern transport practice and enhances their competitiveness in the labour market (Gašparík et al., 2026).

2.2 Modern technological equipment of the laboratory

The quality of the transport laboratory is largely determined by its technical and software equipment. Modern laboratories are equipped with high-performance computer workstations, specialized simulation software, and model-based systems that enable the realistic representation of transport processes.



Fig 4. Dispatcher Workstation Equipped with ESA 44 Interlocking, Including a Remotely Controlled Line since 2024

Simulation software for railway operations modelling plays a significant role. These systems can analyse railway line capacity, train traffic flow, and system responses to various operational scenarios. Users can modify transport parameters, observe the consequences of individual decisions, and evaluate the effectiveness of proposed solutions.

The laboratory may also be equipped with model signalling devices that simulate the principles of real station and line interlocking systems. This provides students with the opportunity to practically verify the principles of traffic management and the functioning of signalling equipment.

An important part of the equipment also includes database and analytical systems for processing transport data. Modern railway transport generates large volumes of data that can be used for transport optimization, operational planning, and improving service quality. Working with data is therefore an essential part of the training of future professionals.

In recent years, elements of virtual reality and interactive visualization systems have also been implemented in laboratories. These technologies enable the creation of realistic simulations of the railway environment and increase the effectiveness of teaching through the visual representation of operational processes (Gašparík et al., 2026).

2.3 Scientific and research activities

The transport laboratory does not serve only an educational function; it also significantly contributes to the scientific and research activities of the department. Research in the field of railway transport is primarily focused on the optimization of transport processes, improving transport safety, and more efficient use of transport infrastructure.

An important area of research is the modelling of transport processes and the simulation of operational scenarios. Using simulation tools, it is possible to analyse the impact of changes in railway timetables, evaluate line capacity, or examine the consequences of infrastructure modernization. Such research activities have practical relevance for the application of these tools in real railway traffic management and for improving operational efficiency.

The laboratory may also be involved in projects funded through national or international grant schemes. The results of this research are subsequently used in the preparation of technical studies, scientific publications, and proposals aimed at improving the quality of railway transport.

Currently, considerable attention is paid to intelligent transport systems and the automation of traffic control. The transport laboratory provides suitable conditions for testing new technological solutions that may contribute to safer and more efficient railway transport (Gašparík et al., 2026), (KZD, 2026).

2.4 Transport laboratory importance for the railway transport future

The development of the transport laboratory is also of fundamental importance for the future of railway transport. Current transport systems face several challenges, including increasing transport volumes, the need to reduce emissions, and the requirement for higher operational efficiency and safety. At the same time, railway transport is considered one of the most environmentally friendly modes of transport; therefore, it is essential to continuously improve its quality and competitiveness.

The transport laboratory makes it possible to test new technological solutions before their implementation in real operations. In this way, it is possible to verify the functionality of new traffic management systems, analyse transport models, or examine the efficiency of modern signalling equipment. The results of laboratory experiments can significantly contribute to the modernization of railway infrastructure and the improvement of transport services.

An important topic for the future is the automation of transport and the implementation of intelligent transport systems. Modern laboratories provide space for research into autonomous control systems, digital technologies, and analytical tools using artificial intelligence. These technologies may fundamentally change the way railway transport is organized and managed in the future.

The importance of the laboratory also lies in the training of qualified professionals who will be able to respond to technological changes in transport. Graduates with experience gained in the laboratory possess practical skills and knowledge of modern technologies, which increases their employability in practice (Gašparík et Šulko, 2016), (Gašparík et al., 2026).

2.5 Cooperation with practice

The importance of the transport laboratory is also reflected in cooperation with industry. The Department of Railway Transport collaborates with transport companies, infrastructure managers, and other organizations operating in the transport sector. This cooperation enables the transfer of knowledge between the academic environment and practice.

Professionals from practice participate in consultations, expert lectures, and the implementation of research projects. Students thus gain up-to-date information on the functioning of railway transport and the requirements of employers. At the same time, the laboratory serves as a space for professional training, presentations of new technologies, and practical demonstrations of transport processes.

Cooperation with practice is also important in addressing specific operational problems. Research activities carried out in the laboratory may contribute to the optimization of transport processes, reduction of operating costs, or improvement of transport safety. In this way, the laboratory represents an important link between academic research and the practical application of acquired knowledge.

The transport laboratory is also used for training participants of professional courses within ŽSR OS 15 - signalman, OS 19 - dispatcher, and OS 42 - signalling technician (KZD, 2026).

2.6 The importance of simulation in railway transport

Simulation technologies represent one of the most important components of modern transport laboratories. In railway transport conditions, they make it possible to analyse operational situations in detail without interfering with real-world traffic. Simulations provide a safe environment for testing new organizational procedures, technological solutions, and approaches to traffic management.

In the transport laboratory, it is possible to simulate both everyday operational situations and extraordinary events that could significantly affect transport flow. These include, for example, train delays, track closure work, signalling system failures, or unforeseen transport incidents. Students and researchers can analyse the consequences of such situations and propose measures to minimize their negative impact.

Simulation systems also enable the evaluation of railway infrastructure capacity. In practice, it is essential to determine how many trains can safely and efficiently pass through a specific section of a railway line or station. The results of simulations can be used in planning infrastructure modernization, the construction of new transport nodes, or the optimization of railway timetables.

The importance of simulations is also increasing in connection with the development of high-speed rail transport and intelligent transport systems. Modern laboratories make it possible to test technological solutions

intended for future use, thereby preparing students for new challenges in the field of transport (Gašparík et al., 2026).

2.7 Modern trends in transport laboratories

Current developments in transport bring new requirements for the technical equipment of laboratories and the content of education. Modern transport laboratories make use of advanced simulation systems, digital modelling, and elements of artificial intelligence. An important topic is also the automation of railway transport and the implementation of intelligent control systems.

One of the trends is the use of virtual reality and digital twins of transport infrastructure. These technologies enable the creation of realistic simulations of railway operations and provide new opportunities for both teaching and research. Through virtual simulations, students can analyse transport situations in a safe environment and experiment with different solutions.

Another significant trend is the use of big data and analytical tools in transport management. Modern transport systems generate large volumes of data that can be used to optimize transport and predict operational issues. The transport laboratory therefore plays an important role in preparing professionals capable of working with modern digital technologies (Gašparík et al., 2026).

3. Benefits of the laboratory for students and the professional community

The transport laboratory makes a significant contribution not only to students of the Department of Railway Transport, but also to the professional community and transport practice. Students gain the opportunity to work with modern technologies, analyse real operational situations, and develop their professional competencies. Practical training carried out in the laboratory significantly improves the quality of the educational process and prepares graduates for the requirements of the modern labour market.

At the same time, the laboratory creates a space for organizing professional seminars, workshops, and presentations focused on current trends in transport. Such activities support the exchange of experience between the academic community and industry professionals. An important advantage is the opportunity to present new technological solutions and test their application under simulated operational conditions.

The contribution of the laboratory is also evident in the field of research and development. Researchers can carry out experiments, analyse transport data, and propose measures to improve transport efficiency. The results of research can subsequently be implemented in real railway operations, thereby contributing to the development of the transport sector.

The modernized transport laboratory also represents a symbol of technological progress and innovation in railway transport. It combines traditional principles of

transport education with modern digital technologies and creates conditions for the training of a new generation of professionals.

Conclusion

Current developments in transport place new demands on the technical equipment of laboratories and on the content of education. Modern transport laboratories make use of advanced simulation systems, digital modelling, and elements of artificial intelligence. An important topic is also the automation of railway transport and the implementation of intelligent control systems.

One of the key trends is the use of virtual reality and digital twins of transport infrastructure. These technologies enable the creation of realistic simulations of railway operations and provide new opportunities for both teaching and research. Through virtual simulations, students can analyse transport situations in a safe environment and experiment with different solutions.

Another significant trend is the use of big data and analytical tools in transport management. Modern transport systems generate large volumes of data that can be used to optimize transport processes and predict operational issues. The transport laboratory therefore plays an important role in preparing professionals capable of working with modern digital technologies.

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